IRRIGATION EFFICIENCIES

in parts of the Selenium Drainage Area on the West Side of the San Joaquin Valley, with a focus on Water District Irrigation Efficiencies

for

Central Valley Region
Calif. Regional Water Quality Control Board
3443 Routier Road, Suite A
Sacramento, CA 95827-3098

by

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Peter Canessa, P.E.
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California Polytechnic State University
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OVERVIEW

OVERVIEW

The Irrigation Training and Research Center (ITRC) of California Polytechnic State University (San Luis Obispo), under contract by the Calif. Regional Water Quality Control Board (Central Valley Region), examined irrigation performances of Broadview, Panoche, Firebaugh, and Pacheco Water Districts. Data was analyzed for the period of 1983 - 1989.

This study was unique in that:

1. A methodology for mathematically describing "Irrigation Efficiency" for an irrigation district was established. The study showed that due to slight differences in assumptions, definitions of terms, and quality of data, the estimates of District Irrigation Efficiency might vary from 48% to 97% (Table DE-22, Section DIE, pg. 40). This variation highlighted the importance of standardizing definitions and calculation techniques in efficiency studies.
2. Previous efficiency studies concentrated on limited aspects of On-Farm Irrigation Efficiency or on very large-scale regional efficiencies. There were no studies in the area which had looked at District Irrigation Efficiency values, which are defined by a political boundary.

Limitations to conclusions exist. Major uncertainties are listed in the report, and include values used for planted acreages, water deliveries, effective precipitation, extent of groundwater inflow to districts, actual crop evapotranspirations, and the extent of reclamation leaching. The identification of uncertain values will assist in targeting needs for better data collection.

Conclusions were:

1. District Irrigation Efficiencies appear to be reasonable in Firebaugh, Panoche, and Broadview Water Districts (F,Pan, and B WD's).
2. The Pacheco Water District Irrigation Efficiency is lower than the Efficiency of (F,Pan, and B WD's). This indicates (a) a lower level of On-Farm irrigation water management and/or (b) less repumping of drain water by Pacheco WD. In the other districts, pumps pick up water from some surface drains and recycle that water back into the irrigation canals.
3. On-Farm Irrigation Efficiencies will be lower than District Irrigation Efficiencies in all cases, because surface and subsurface drainage water from individual fields (causing low on-farm Irrigation Efficiencies) is often re-circulated within District boundaries, either intentionally or inadvertently (in the form of crop water uptake from a high water table).

4. Figure 1 below (derived from Tables DE-26 and DE-27), shows a general trend toward improved District Irrigation Efficiency in recent years. The report discusses possible reasons, including political awareness, the drought, and improved on-farm irrigation techniques.

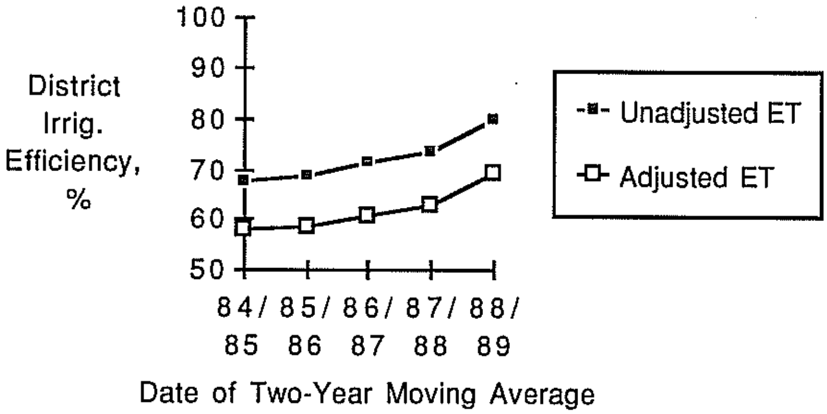

Figure 1. Summary of Two-Year Moving Average District Irrigation Efficiencies Using Two Estimates of Crop Evapotranspiration (ET). Average data is from (F, Pan, and B WD's). "Unadjusted ET" is a measure of efficiency which assumes ET from healthy crops on all the fields. "Adjusted ET" is an unconventional ET estimate which de-rates the ET, based upon aerial photo evidence of bare spots and poor growth in some of the fields throughout the area.

5. It appears that District Irrigation Efficiencies can be improved through three general areas:
   a. Improved On-Farm Irrigation Efficiency (item 6 below)
   b. Improved irrigation district recirculation of drainage water.
   c. Improved irrigation and agronomic practices which would result in better crop yields and better first-time beneficial usage of water when it is applied on-farm (ie, elimination of "spotty" growth and bare spots on fields).
6. (F,Pan, and B WD's) presently (1988-89 data) have District Irrigation Efficiencies of about 80% (assuming full, unadjusted crop evapotranspiration). In this case, an improvement of District Irrigation Efficiency of 10% (to about 90%) might require an increase of On-Farm Irrigation Efficiency on the order of 10-20% (to about 80%). Any efficiency increases beyond that level would almost certainly result in under-irrigation and an increase in soil salinity. In other words, attainable upper values of On-Farm Irrigation Efficiency are about 80% (as limited by evaporation, hardware, scheduling, soil, and weather variations). On-farm Irrigation Efficiency values greater than 80% are almost always accompanied by under-irrigation. Under-irrigation in this arid area will result in eventual salt buildup in the soil.

7. District Irrigation Efficiencies of close to 90% are only possible in areas with high water tables. In these areas, the deep percolated irrigation water on one field may serve as a source of sub-irrigation water on another field, or even on that same field later on (when the roots expand to deeper soil zones). Therefore, portions of these districts which have no high water tables may have maximum attainable District Irrigation Efficiencies of 80%, unless under-irrigation occurs.

SUMMARY/CONCLUSIONS

Summary/Conclusions

An original objective of this Project was to estimate reasonable, attainable On-Farm Irrigation Efficiencies within four Water Districts: Broadview (BWD), Firebaugh (FCWD), Panoche (PANWD), and Pacheco (PACWD). Upon completing a search for data and prior reports regarding any type of Irrigation Efficiency studies in the study area (see the sections in this report regarding "*Review of Pertinent Literature*" and "*Abbreviated Comments Regarding Literature*"), it was concluded that there was insufficient information to make a detailed report regarding On-Farm Irrigation Efficiencies.

Therefore, a methodology was developed to estimate District Irrigation Efficiencies. It is known that District Irrigation Efficiencies are higher than On-Farm Irrigation Efficiencies. This is because some of the uncollected On-Farm tailwater runoff is picked up in District surface drains and re-used on other fields/farms. Also, some of the deep percolation (water which goes below the plant root zone) during an On-Farm irrigation will show up as a high water table in a downslope field. That high water table will provide some of the crop evapotranspiration needs of the downslope field.

The detailed methodology used to estimate District Irrigation Efficiencies is described in the section entitled "*District Irrigation Efficiencies*". A water balance was established for each district in an effort to quantify all the components. The basic definition of Irrigation Efficiency (regardless of the area to be considered) is:

$$\text{Irrigation Efficiency} = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} \times 100$$

Computation of District Irrigation Efficiency

District Irrigation Efficiencies (DIE's) were computed using eight different assumptions. In some districts, this resulted in only 4 different values. The eight formulas for computation of DIE for Panoche, Pacheco, and Firebaugh Water Districts were:

1. $$\frac{\text{(Unadjusted Evapotranspiration} - \text{Shallow Groundwater Contribution)}}{\text{(Controlled Water Supplies into the District)}}$$

2. $$\frac{\text{(Unadjusted Evapotranspiration)}}{\text{(Controlled Supplies into the District)}}$$

3. $$\frac{\text{(Unadjusted Evapotranspiration} - \text{Shallow Groundwater Contribution)}}{\text{(Controlled Supplies} + \text{All Other Surface Water Supplies into the District)}}$$

4. $\dfrac{\text{(Unadjusted Evapotranspiration)}}{\text{(Controlled Supplies + All Other Surface Water Supplies into the District)}}$

5. $\dfrac{\text{(Adjusted Evapotranspiration - Shallow Groundwater Contribution)}}{\text{(Controlled Water Supplies into the District)}}$

6. $\dfrac{\text{(Adjusted Evapotranspiration)}}{\text{(Controlled Supplies into the District)}}$

7. $\dfrac{\text{(Adjusted Evapotranspiration - Shallow Groundwater Contribution)}}{\text{(Controlled Supplies + All Other Surface Water Supplies into the District)}}$

8. $\dfrac{\text{(Adjusted Evapotranspiration)}}{\text{(Controlled Supplies + All Other Surface Water Supplies into the District)}}$

The computations in the denominator were identical for Broadview WD. However, a high water table exists throughout Broadview WD so there is no question about a high water table contributing to crop ET. However, there is a question in Broadview WD regarding the possibility of all of the deep percolation being useful as beneficial reclamation leaching (due to a prior history of highly saline soils within Broadview WD). Therefore, the numerator used for Broadview WD was:

Calculations	Numerator
1,3	Unadjusted Evapotranspiration but NO Reclamation Leaching
2,4	Unadjusted Evapotranspiration PLUS Reclamation Leaching
5,7	Adjusted Evapotranspiration but NO Reclamation Leaching
6,8	Adjusted Evapotranspiration PLUS Reclamation Leaching

Two-year moving averages were used in the discussions because it is difficult to accurately estimate seasonal soil moisture changes, whether water delivered one year is used on nest year's crop, and how to divide up water use on crops such as small grains which span two calendar years. Results for individual water districts are summarized in Tables DE-11, DE-14, DE-17, and DE-20.

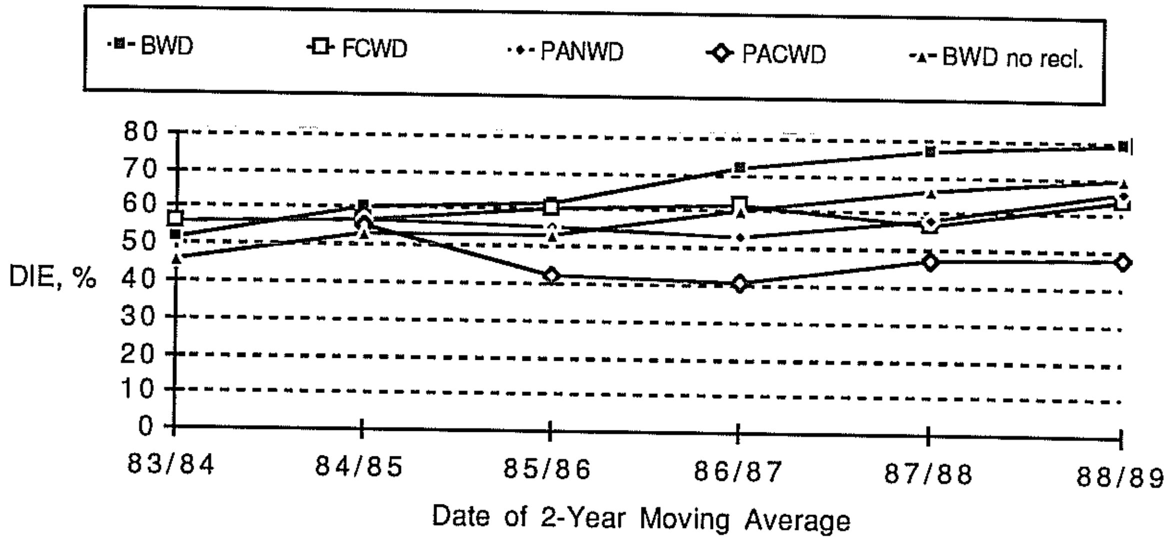

Figure SC-1. District Irrigation Efficiencies using the "Most Technically Correct" definition of Irrigation Efficiency. It uses an "adjusted ETc" value which de-rates the crop evapotranspiration based upon observed uneven crop growth in the fields.

Figure SC-1 used results from computation method #7 (defined above) for Panoche, Pacheco, and Firebaugh Water Districts. For Broadview WD, calculations were done with and without the assumption of deep percolation being beneficially used as reclamation leaching. It can be seen that once the Broadview soils are reclaimed and all of the deep percolation is no longer counted as beneficial, the Broadview performance will be very similar to that of Panoche and Firebaugh WD's. It should be pointed out that the "adjustment" of crop ET values for non-uniform crop growth and bare spots in the field has not been done before, as far as the authors are aware. The result of this "adjustment" is a lower-than-usual estimate of District Irrigation Efficiency. However, it seems logical to the authors that crop coefficients must be adjusted based upon reduced plant material and bare spots in the field.

Figure SC-2 used a more "Conventional approach" to estimated District Irrigation Efficiencies. SC-2 uses an "un-adjusted crop ET", and ignores any ET contribution from a high water table (except in Broadview). It also accounts for all external surface and pumped water sources. This ET was estimated using conventional crop coefficients which have standard adjustments for normal field stress and occasional wet soil surfaces.

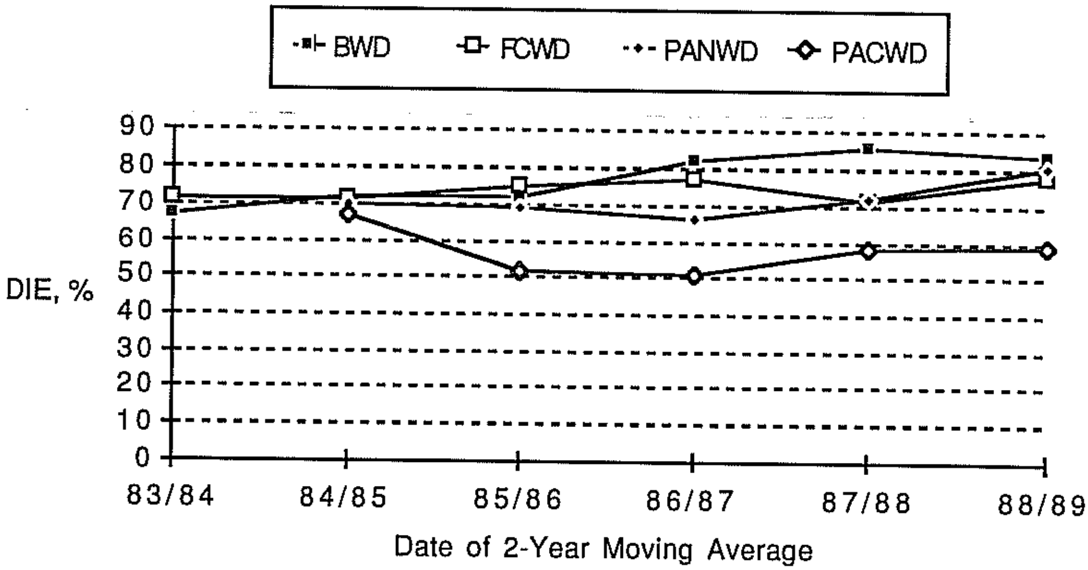

Figure SC-2. District Irrigation Efficiencies using a "Conventional Approach" to the definition of Irrigation Efficiency. It uses typical estimates of crop ET (which ignore bare spots and uneven growth), ignores water table contributions to ET (except for BWD), and accounts for all external surface water supplies plus pumping.

Figures SC-1 and SC-2 show that the 88/89 performances of Broadview, Firebaugh, and Panoche Water Districts were almost identical (ignoring reclamation leaching in Broadview). However, Pacheco Water District has a 10-20% lower estimated District Irrigation Efficiency. This indicates a lower level of on-farm water management within Pacheco WD and/or less District recycling of surface and subsurface drain water within District boundaries. The Pacheco WD drain water may be beneficially used elsewhere; such uses were not examined in this study.

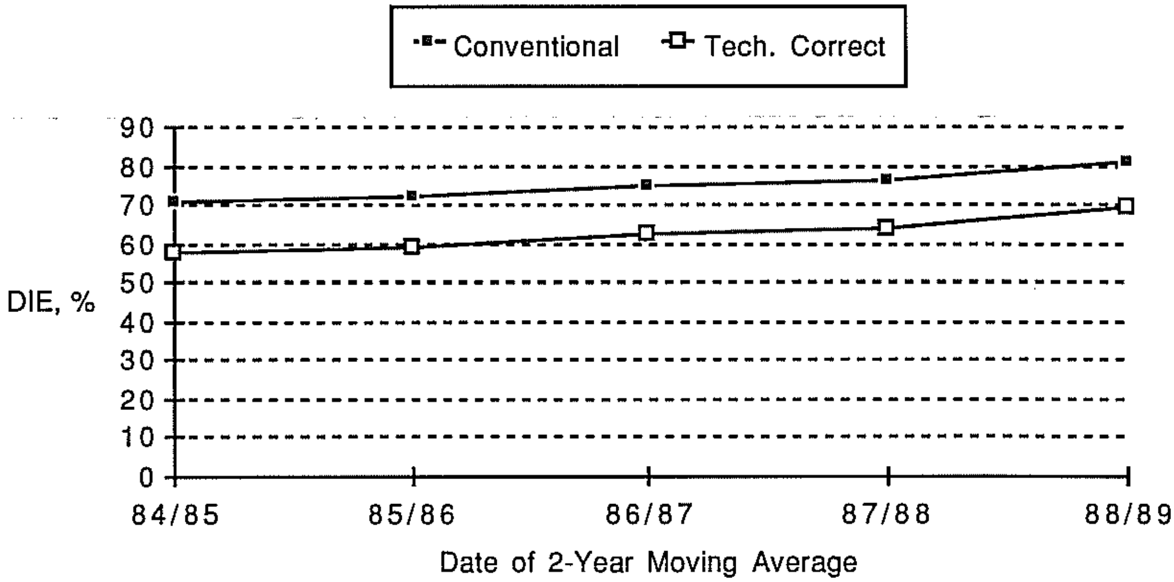

Figure SC-3. Summary of Two-Year Moving Average District Irrigation Efficiencies Using Two Different Estimating Techniques: "Most Technically Correct" and "Conventional". Broadview, Firebaugh, and Panoche WD's.

Figure SC-3 indicates that District Irrigation Efficiencies are "reasonable" in Firebaugh, Panoche, and Broadview Water Districts. There is a definite general trend toward improved District Irrigation Efficiency in the period of 1984/85 - 1988/89. The report ("*District Irrigation Efficiencies*") discusses possible reasons for this improvement in detail. Some possibilities include:

1. The drought. The drought has certainly improved farmer awareness of the need for good On-Farm water management.
2. Kesterson. The existence of a selenium problem in Kesterson Reservoir broke into the headlines in 1985. This brought about a heightened awareness of the need for good District and On-Farm water management.
3. Improved On-Farm irrigation technology. The San Joaquin Drainage Program, and the California Dept. of Water Resources have both supported demonstrations and studies of improved On-Farm irrigation technologies in the area. A Mobile Lab is available to provide assistance to growers in the area, and many of the growers are familiar with recommendations given to farmers through the Westlands Water District Water Conservation and Drainage Reduction program which began in earnest around 1986.

4. Improved flexibility of water delivery by some of the Districts to the farmer. Some of the Districts have instituted new, more flexible delivery policies. Farmers are allowed more latitude in changing flow rates and irrigation durations.

Attainable **District** Irrigation Efficiencies

In 1988/89, Firebaugh, Broadview, and Panoche WD's had District Irrigation Efficiencies which were quite high (about 80%) if computed in a "conventional" manner. For a district with a high water table, a true District Irrigation Efficiency of 90% would be extremely good if no or little under-irrigation exists On-Farm. Such a high District Irrigation Efficiency (without under-irrigation) is only possible in high water table areas, where much of the deep percolation is eventually used to satisfy crop ET requirements within the same district.

For irrigation Districts outside of high water table areas, maximum attainable District Irrigation Efficiencies are typically less than 80% (assuming no under-irrigation). Factors which limit these efficiencies include non-uniform application of On-Farm by all irrigation methods (surface,sprinkler, and drip), evaporation losses, conveyance and seepage losses within District distribution systems, and the impossibilities of having perfect irrigation timing. These high values are only attainable if all surface water runoff is recycled, and there are no operational spills from district conveyance canals.

Based upon the statements above, it may be possible for Broadview, Firebaugh, and Panoche Water Districts to still improve District Irrigation Efficiencies by 5-10%, and still have little or no under-irrigation. However, it is quite difficult to "squeeze" the last bit of performance out of a system. It appears that improvements in District Irrigation Efficiencies would come from:

1. Improved On-Farm Irrigation Efficiency. A true improvement of District Irrigation Efficiency by 5 -10% would probably require an improvement of On-Farm Irrigation Efficiency by 10-20% (to about 80%). There is always a wide range of individual On-Farm Irrigation Efficiencies within a District. An emphasis would need to be made on improving very low On-Farm Irrigation Efficiencies of some farmers, and actually reducing very high On-Farm Irrigation Efficiencies of other farmers who may be under-irrigating without realizing it. (See the later section in this chapter for more details.)
2. Improved District recirculation of surface and subsurface drainage water. Much of the tile drain water is picked up in District surface drains, and tailwater in the area often goes into the surface drains. Improved recirculation of this water (which already occurs in some areas) will keep the water within District boundaries.

3. Improved agronomic and On-Farm irrigation practices which would result in better crop yields. The "adjusted ETc" method of computing District Irrigation Efficiencies effectively reduced the estimated IE values by 10%, due to estimates that water was being applied to areas of fields which did not have healthy crops. If those fields could be managed to have more uniform and healthier crop stands, the evapotranspiration of the applied irrigation water would increase. Therefore, assuming a constant supply, the District Irrigation Efficiency would increase.

Attainable On-Farm Irrigation Efficiencies

Potential, reasonably attainable on-farm irrigation efficiencies are remarkably similar regardless of irrigation method......if the irrigation method is appropriate for the crop and soil type. In general, it is understood that a reasonable, attainable value of on-farm irrigation efficiency is somewhere between 75 - 80%, based upon the following assumptions/conditions:

1. No under-irrigation will occur on the field (with the possible exception of 1/8th of the field, using certain definitions of efficiency). Acceptance of under-irrigation will raise the potential irrigation efficiency.
2. This value is a seasonal value, and accepts the fact that individual irrigation events have have higher and lower irrigation efficiencies.
3. A high reasonable and attainable Distribution Uniformity (DU - defined as the ratio of the minimum amount of water received anywhere on a field, divided by the average amount) is 80%. This is a FIELD DU. Higher DU values are generally quoted from results originating in small research plots, or studies which only deal with a single furrow or the overlap of water around 4 sprinklers.
4. It is impossible to schedule irrigations perfectly. There are human and physical flaws.

It is estimated that present on-farm irrigation efficiencies (IE) AVERAGE somewhere between 50-65% in most of the study area. This report does not contain sufficient documentation to substantiate that estimate; the estimate is based primarily upon:

1. The fact the average on-farm irrigation efficiencies will generally be lower than irrigation district efficiencies in a high water table area. As stated before, this is due to the fact that deep percolation for one irrigation or farm will often serve as the supply water for ET of crops on another field. Also, there is some district recirculation of water in this study area.
2. Similarly irrigated fields in other areas of California have similar on-farm IE's.

This study area does not have any unusual characteristics which should prevent the eventual attainment of values of 75 - 80% on-farm IE. However, some significant changes would need to be made. These would include:

1. Irrigation district water deliveries:
   a. Farmers must be allowed to shut off water (or change their flow rate) with a maximum of 6 hours advance notice.
   b. Water delivered to farms must be accurately metered by VOLUME.
   c. Farmers must receive excellent feedback regarding their water use BY FIELD and BY IRRIGATION, in comparison to estimates of what their neighbors use and what a "reasonable use" might be. This will require strict adherence to rules about what lands can be served by what turnouts.
2. Tailwater return systems must be installed on furrow irrigated fields.
3. Many fields which are currently surface irrigated (border strip or furrow) must be converted to pressurized irrigation. The aerial photos showed graphic evidence of many fields with sand streaks intermingled with heavier soils.
4. Hand move sprinkler systems must use alternate sets during the growing season, and close lateral spacing (less than 30') during pre-irrigations.
5. Hand move sprinkler systems must be checked for nozzle uniformity and lack of wear, and pressure regulators must be installed on individual sprinklers.

It is important to note that a present AVERAGE Irrigation Efficiency value means that some farmers already have efficiencies which are considerably higher than that value. There are also differences in the study area regarding the quality of irrigation district delivery flexibility and flow measurement/record keeping.

<u>Limitations to Interpretation</u>

Table DE-22 illustrates the difficulty in accurately assessing the Irrigation Efficiency within a District (the same problems exist for Field and Regional estimates). Depending upon the assumptions used, and the accuracy of individual values, the <u>estimates of Broadview Water District Irrigation Efficiency can vary from 48% to 97%</u>.

The analysis procedure is detailed in this report, and it is strongly recommended that the procedure be adopted as a "standardized" method for analysis of irrigation efficiencies. A value of this procedure (which compares several computation results) is that it points out strengths and weaknesses in existing data bases. It also shows the relative importance of various assumptions and factors in the Irrigation Efficiency definition.

An important conclusion is that our abilities to compute values, and our comprehension of the inter-relationships between various factors, exceed the accuracy of the basic data. The data has been acquired from agencies and studies which did not need the data quality and high accuracy required for firm Irrigation Efficiency estimates.

Leaching Requirement

A section has been included in the report which documents the procedure used to estimate the Leaching Requirement. The Leaching Requirement is based upon the salt tolerance of the most salt-sensitive crop with a "typical" root zone depth in a standard rotation. For this study area, that crop was designated as tomato.

CONTRACT / INITIAL WORK

CONTRACT

This report is the result of a water management study for the Water Resources Control Board (WRCB) under Standard Agreement #45902062, between the WRCB and the Foundation of California Polytechnic State University, San Luis Obispo. All work was conducted by the Irrigation Training and Research Center (ITRC), under the direction of Dr. Charles Burt. Principal co-investigators were Peter Canessa and John Parrish.

The purpose of the contract was to "assist the Agency in its goal of reducing concentrations of selenium in subsurface drainage from agricultural irrigation." To do this, the ITRC was to conduct a study to evaluate the current and potential efficiency of water management and irrigation practices on agricultural lands in the Grassland Basin of the Central Valley. This study examined Firebaugh Water District, Broadview Water District, Panoche Water District, and Pacheco Water District. Areas of Central California Irrig. District and Charleston Drainage District were not included because of the small size and/or difficulty of obtaining information specific to the study area.

At a minimum, the study was to include:

1. An evaluation of the adequacy of available information in estimating present on-farm irrigation efficiencies in the area of concern.
2. An examination and evaluation of information which indicates historical irrigation performances (a) before 1985, and (b) since 1985.
3. An estimate of reasonable attainable on-farm irrigation efficiencies within the region.

INITIAL WORK

The ITRC performed the following initial tasks:

1. Information regarding estimates of irrigation performance in the area was gathered. Sources included information held by the Agency, Mobile lab (Los Banos) results, USDA/ARS research, studies by engineering companies, reports by the water districts themselves, reports by the San Joaquin Valley Drainage Task Force, memos from Bay-Delta subcommittee meetings, private conversations with farmers and district personnel, and other sources.
2. The information from task (1) was reviewed and summarized. Results from this task were provided to the Regional WQCB in Sacramento on January 29, 1991:

a. A section "Review of Pertinent Literature Providing Efficiency Estimates" which included (a) a Bibliography of compiled data, plus (b) a summary of all efficiency estimates which are known to have been made for the study area.

b. A section "Abbreviated Comments Regarding Background Literature" in outline format. It consisted of brief notes made regarding all the accumulated literature, by topic.

3. Each of the irrigation districts in the study area was sent a questionnaire regarding water deliveries and practices.

4. Aerial photos of individual fields, taken by ASCS, were obtained for the complete area for the winter and summer of 1984 and the summer of 1989. These photos were organized, and fields were rated on a 1-5 scale for (a) uniformity of the crop and for (b) existence of bare spots. Limited field checks were made to verify locations, scale, and various features.

It became obvious that existing information regarding irrigation efficiencies at any level (ie, basin, DAU, irrigation district, or on-farm) within the study area had the following characteristics:

1. **Studies used inconsistent terminology and methodologies.**
2. **There were large holes in the data for all studies.**
3. **Many of the reports merely repeated questionable statements made by previous reports.**
4. **ITRC staff did not have a high degree of confidence in any "efficiency" values which had been reported for the study area.**

The mandate of this project was to estimate on-farm irrigation efficiency. However, there simply was not sufficient/reliable data available to make such computations. It is known, however, that <u>on-farm</u> irrigation efficiencies cannot be greater than <u>irrigation district</u> irrigation efficiencies. Therefore, considerable effort was made to define the irrigation efficiency for each of the various districts, by year. The results can be found in the section "District Irrigation Efficiencies".

The section "District Irrigation Efficiencies" is fairly self-explanatory. The definitions are fairly precise, and "irrigation efficiencies" are calculated using 8 possible acceptable procedures which can all fall within the definition of "Irrigation Efficiency". A sensitivity analysis is also provided.

DISTRICT IRRIGATION EFFICIENCIES

DISTRICT IRRIGATION EFFICIENCIES

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DISTRICT IRRIGATION EFFICIENCIES

<u>Introduction</u>

One of the original objectives of this Project was to estimate reasonable, attainable on-farm irrigation efficiencies. There is insufficient published information regarding efficiencies <u>at the individual field level</u>. However, the average individual field efficiency in a District cannot be greater than the District average. Thus, four Districts in the study area, Broadview Water District (BWD), Firebaugh Canal Water District (FCWD), Panoche Water District (PANWD), and Pacheco Water District (PACWD), were analyzed for average District irrigation efficiencies.

An annual "water balance" was developed for each District. The components of the balance are illustrated in Figure DE-1. As the components were evaluated, several estimates were made of annual District Irrigation Efficiency. District Irrigation Efficiency is defined as...

$$\text{District Irrigation Efficiency} = \frac{\text{Applied Irrigation Water which is Beneficially Used}}{\text{Applied Irrigation Water}} \times 100$$

where the boundary of beneficial use is the <u>District</u>

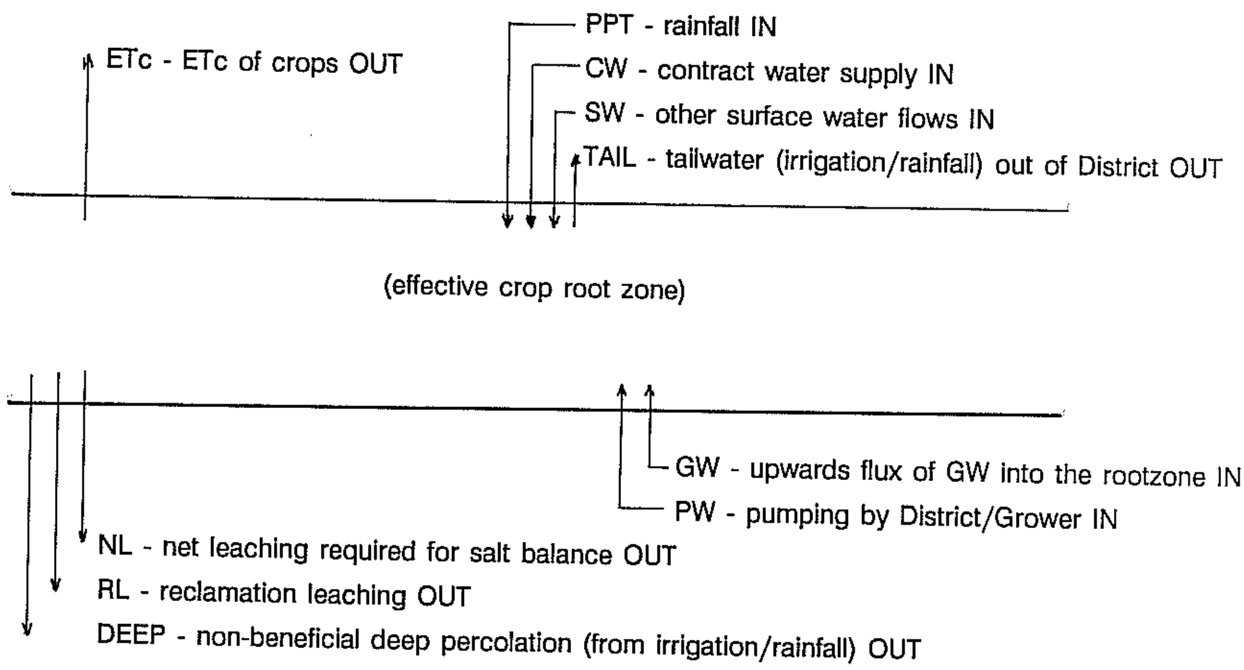

Figure DE-1 - Schematic of District Water Balance

"Beneficial use of applied irrigation water" includes crop ET, leaching to maintain a salt balance, and leaching for reclamation. "Applied irrigation water" refers to water entering the District boundaries including contract water, District/Grower wells, upwards flux into the root zone of groundwater originating from outside the District, and surface inflows from outside the District. Rainfall can be (a) surface runoff, or (b) infiltrated soil moisture that could end up as crop ETc, salt balance leaching, reclamation leaching, or non-beneficial deep percolation.

The balances were determined for calendar years 1981 to 1989 depending on what information was available. The objectives were...

(a) identify the relative level of District Irrigation Efficiency

(b) any trends up or down.

In identifying these trends the major question is whether there is room for further improvement. That is, if a high relative level is seen, or if a trend is seen to have peaked, is the current District Irrigation Efficiency an absolute peak- one limited by physical conditions or existing technology? Or is it an economic peak- one governed by internal benefit/cost ratios and/or other external factors?

Procedure

Spreadsheets were developed for each of the Districts for each year of available information. The following components were evaluated...

AC - acreages of major crops grown that year

CW - contract water supplied

ETc - annual ETc for each crop

ET_ADJ - a correction factor accounting for stunted growth or bare spots

EFF_PPT - effective rainfall for each crop (to include that used for crop ETc, maintenance leaching, and reclamation leaching)

GW - upwards flux of groundwater that originates outside the District

LF - net maintenance leaching required to maintain long-term salt balance at an acceptable soil salinity

PW - District/Grower pumping of well water

RL - beneficial leaching for soil reclamation

SW - other surface inflows to the District

For comparison purposes the beneficial use of applied irrigation water, BEN, was calculated six different ways. The first four were for Broadview Water District and included totals with and without considering reductions to crop ET due to stunting or bare spots in individual fields (ET_ADJ); and with and without considering leaching for soil reclamation (RL, significant only in Broadview Water District). All of these four variations included upwards flow from groundwater since it was assumed that the total District is affected by a shallow water table that receives water from outside the District boundaries.

The other two variations were done for the other three Districts (Firebaugh Canal, Panoche, and Pacheco Water Districts) since there is a question as to whether the entire District in each case is affected by a high water table. They were with and without the upwards contribution from groundwater. The six calculations were...

1) BEN1 = AC * (ETc + LF - EFF_PPT - GW)
2) BEN2 = AC * (ETc + LF + RL - EFF_PPT - GW)
3) BEN3 = AC * ((ETc * ET_ADJ) + LF - EFF_PPT - GW)
4) BEN4 = AC * ((ETc * ET_ADJ) + LF + RL - EFF_PPT - GW)
5) BEN5 = AC * (ETc + LF - EFF_PPT)
6) BEN6 = AC * ((ETc * ET_ADJ) + LF - EFF_PPT)

Further, the amount of irrigation water available for application in the District (AW) was calculated in two ways, with and without considering other surface inflows (SW was only significant in Broadview Water District). The calculations were...

1) AW1 = CW + PW
2) AW2 = CW + PW + SW

Finally, there were eight variations of District Irrigation Efficiency calculated for each District. In Broadview's case the variations were determined by dividing BEN1-4 by AW1-2. For the other three Districts, BEN1, BEN3, BEN5, and BEN6 were divided by AW1 and AW2.

Referring to Figure DE-1 it should be noted that the components TAIL and DEEP were not explicitly quantified. Again, the definition of District Irrigation Efficiency (DIE) is the total beneficial use <u>within District boundaries</u> divided by the total applied water. Regardless of any further use of TAIL and DEEP by downstream Districts, they are <u>non-beneficial</u> use for the purposes of this project. The <u>Discussion of Procedure</u> and <u>Broadview Water District</u> s provide a detailed explanation of the estimation of beneficial reclamation leaching (RL).

<u>Calculation of Crop ETc</u>

The annual crop ETc_{year} was obtained by summing the monthly ETc's and...

ETc = Kc * ETo

where: ETc = monthly crop evapotranspiration

Kc = average monthly crop coefficient

ETo = monthly reference ET (grass reference)

Monthly ETo for 1983-1989 was obtained from CIMIS Station #7 at Telles Ranch. ETo for 1981 and 1982 are longterm average ETo's from Station 7. ETo's used are seen in Table DE-1. Kc's were developed using the method of UC Extension Leaflets 21427 and 21428. The information in these leaflets for individual crops were modified for local conditions and planting/harvest dates. Table DE-2 is a summary of the "pivot" crop coefficients, KC1, KC2, KC3 and the pivot dates A, B, C, and E as defined in these Leaflets. Tables for Kc's and ETc's of the individual crops are included in Appendix DE.

TABLE DE-1 - Monthly ETo in Inches at CIMIS Station #7, Telles Ranch

	1981*	1982*	1983	1984	1985	1986	1987	1988	1989
Jan	0.95	0.95	0.85	0.98	0.96	1.24	1.32	1.21	1.49
Feb	1.96	1.96	1.80	2.16	2.37	2.03	1.71	2.65	1.70
Mar	3.71	3.71	3.00	4.60	3.53	3.50	3.78	5.20	3.83
Apr	5.68	5.68	4.84	5.77	6.43	5.59	6.65	4.98	5.75
May	7.93	7.93	8.80	8.96	7.56	7.50	7.71	7.25	7.86
Jun	8.40	8.40	9.57	8.55	8.57	8.04	8.29	7.47	8.58
Jul	8.52	8.52	9.24	8.57	8.19	7.90	8.25	8.40	8.95
Aug	7.15	7.15	7.48	7.11	7.19	7.30	7.06	6.72	7.40
Sep	5.30	5.30	5.73	6.28	5.40	5.07	5.40	5.31	5.12
Oct	3.61	3.61	3.45	3.83	3.88	4.02	3.66	3.30	3.94
Nov	1.56	1.56	1.35	1.75	1.81	2.54	1.62	1.59	1.98
Dec	0.86	0.86	0.95	1.74	0.77	0.73	1.39	0.94	1.05
Annual	55.63	55.63	57.06	60.30	56.66	55.46	56.84	55.02	57.65

*-AVERAGE YEAR DATA

TABLE DE-2 - "Pivot" KC's and Dates used to Determine Monthly Crop Kc's

	PIVOT Kc s			PIVOT DATES					
CROP	Kc 1	Kc 2	Kc 3	A	B	C	D	E	% OF A-E=D
ALFALFA	0.40	1.00	0.40	01/01	01/01	01/31	11/06	12/31	85
BARLEY	0.19	0.99	0.32	12/01/90[2]	12/24/90	03/02/91	04/15/91	05/31/91	75
DRY BEANS	0.14	1.15	0.30	04/01	04/30	05/25	06/29	07/31	74
COTTON	0.14	1.06	0.10	04/10	05/12	07/06	08/17	10/15	69
CORN	0.18	1.10	0.45	04/16	05/07	06/28	08/06	09/15	74
MELON	0.18	1.10	0.10	04/01	05/06	06/14	06/18	07/15	75
RICE	0.95	1.25	0.95	04/01	04/26	05/28	06/29	08/31	59
SEED ALFALFA	0.20	1.10	0.34	12/01/90	12/24/90	03/02/91	06/11/91	08/15/91	75
SORGHUM	0.16	1.05	0.45	05/01	06/04	07/04	08/04	09/30	63
STONEFRUIT/ALMOND	0.65	0.98	0.85	03/10	03/10	06/09	09/14	11/01	80
SUGARBEETS - NORTH	0.23	1.10	0.95	05/20/90	06/10/90	07/20/90	01/26/91	03/15/91	84
SUGARBEETS - SOUTH	0.24	1.13	0.90	01/20/90	03/17/90	05/03/90	06/25/90	08/31/90	70
TOMATO	0.24	1.12	0.70	04/01	05/08	06/28	07/19	08/31	72
VEGETABLES	0.43	1.18	1.18	02/01	02/28	04/12	05/01	05/31	75
WALNUT/APPLE	0.70	1.17	1.00	03/10	03/10	06/03	09/21	11/09	80
WHEAT	0.22	1.17	0.38	12/01/90	12/24/90	03/02/91	04/15/91	05/31/91	75

1. Date D (full growth) is determined by calculating a percentage of time from date A to date E
2. Some crops overlap the calendar year, thus Kc's were determined using the 1990-1991 crop year

Calculation of Effective Rainfall

Effective rainfall (EFF_PPT) is defined as that rain which infiltrates and either...

- stays in the effective rootzone of the crop, available for crop ET,
- or is effective in satisfying maintenance (net) or reclamation leaching (reclamation leaching was only significant for Broadview Water District).

Monthly rainfall records were obtained for the USWB station at Mendota Dam and are seen in Table DE-3. (Rainfall records from CIMIS Station #7 were not used due to poor site conditions.)

TABLE DE-3 - Gross Monthly Rainfall in Inches Reported at Mendota Dam

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	3.28	1.61	0.70	3.53	0.10	0.60	0.11	1.14	1.18	0.29
Feb	2.32	0.78	0.66	1.80	1.38	0.09	2.92	1.90	0.46	1.15
Mar	1.46	3.57	2.77	4.57	0.49	0.62	2.44	2.15	0.18	0.88
Apr	0.22	1.32	1.81	0.84	0.03	0.14	0.51	0.00	1.13	0.13
May	0.18	0.00	0.00	0.45	0.00	0.00	0.12	0.12	0.29	0.09
Jun	0	0.00	0.12	0.00	0.08	0.05	0.00	0.00	0.00	0.00
Jul	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0	0.00	0.78	0.77	0.00	0.00	0.36	0.00	0.00	1.36
Oct	0	0.37	0.60	0.59	0.55	0.49	0.00	0.83	0.00	0.64
Nov	0.11	2.25	1.91	1.14	1.05	3.11	0.00	0.59	0.67	0.31
Dec	0.3	0.27	1.03	1.54	2.67	0.97	0.35	1.23	2.33	0.00
Annual	7.87	10.17	10.38	15.23	6.35	6.07	6.81	7.96	6.24	4.85

TABLE DE-4 - US Bureau of Reclamation Correction Factors for Effective Rainfall on Fallow and Cropped Ground

EFFECTIVE PPT IN SEASON UP TO GROSS INCHES/MONTH	X % = NET	EFFECTIVE PPT FALLOW UP TO GROSS INCHES/MONTH	X % = NET
0	90	0	40
1	87.5	1	60
2	83.3	2	70
3	75	3	72.5
4	66	4	64
5	56.7	5	56.7
6	56.7	6	56.7

Adjustments for surface runoff and evaporation were made using US Bureau of Reclamation (USBR) correction factors for monthly rainfall that consider fallow and cropped ground separately, seen in Table DE-4. If the crop coefficient (Kc) was over .15, then the cropped ground factors were used.

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TABLE DE-5a - Calculated Fallow Ground Infiltrated PPT for Melons

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.00
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.82
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.26
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.12
									0.00
Annual	5.70	4.80	8.72	3.78	3.36	4.08	4.64	2.72	2.35

TABLE DE-5b - Calculated Cropped Ground Infiltrated PPT for Melons

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	1.16	1.69	1.16	0.10	0.17	0.57	0.11	1.25	0.20

The Tables containing estimates for infiltrated rainfall for each crop for each year are contained in Appendix DE. Tables DE-5a and 5b are examples for melons. Two Tables were calculated for each year, one for infiltrated rainfall in-season and one for infiltrated rainfall off-season. The process for determining total effective rainfall is explained by the following steps...

1. in-season infiltrated rainfall up to the monthly ETc is effective rainfall, called EFF_{ETc}.

2. off-season infiltrated rainfall that will satisfy an estimated maximum soil moisture depletion (SMD) in the six foot root zone is effective rainfall, called EFF_{SMD}. The idea is that some off-season infiltrated rainfall would be effective in satisfying the SMD for a pre-irrigation. This maximum SMD was calculated as some percentage of the available water holding capacity (AWHC) in the maximum effective root zone (six feet) of the District. AWHC's were estimated from Soil Conservation Service data for average soils in each District. Using melons as an example...

$SMD_{max} = AWHC * ERZ * SMD / 100$

where: SMD_{max} = maximum fallow-ground effective rainfall
AWHC = available water holding capacity, 2 inches/foot
ERZ = maximum effective rootzone in the District, 6 feet
SMD = maximum depletion of AWHC in ERZ by melons, 30%

and...

$$SMD_{max} = 2 \text{ in/ft} * 6 \text{ ft} * 30\% / 100$$
$$= 3.6 \text{ inches}$$

Thus some off-season infiltrated rainfall for melons would be used to satisfy the 3.6 inches. (30% SMD was assumed for melons because of the irrigation management practiced with that crop. For a crop such as cotton, 60% was used because of the drydown period.)

3. Whether the rest of the infiltrated rainfall (in-season beyond monthly ETc or off-season beyond the maximum SMD) is effective depends on the leaching requirements, either to maintain a salt balance or for reclamation. Call the un-categorized, infiltrated rainfall IN_PPT. Then...

- if IN_PPT < leaching requirements/reclamation then EFF_{LR} = IN_PPT

- if IN_PPT > leaching requirements/reclamation then EFF_{LR} = leaching requirements/reclamation

(Refer to the <u>Discussion of Procedure</u> and <u>Broadview Water District</u> s for an explanation of how reclamation leaching was determined.)

4. Finally the total effective rainfall, EFF_PPT = $EFF_{ETc} + EFF_{SMD} + EFF_{LR}$

<u>District Spreadsheets</u>

Spreadsheets were developed for each District for each year of available data. Then a summary sheet was prepared to consolidate the individual years. The summary sheets include three s, one for single year calculations, one for two-year moving averages, and one for three-year moving averages. The two-year and three-year moving averages are considered more valid than the single year because of the overlap of crop and water years.

Tables DE-6 and DE-7 are an example of 1985 data for Broadview Water District and the summary for BWD (Table DE-7 are two-year moving averages). Tables DE-8 and DE-9 are 1985 data for Firebaugh Canal Water District and a summary of two-year moving average District Irrigation Efficiencies for FCWD. Notes for the individual columns are (refer to Table DE-6 for columns 1-12, Table DE-7 for columns 13-25, Table DE-8 for columns 11a and 12a, and Table DE-9 for columns 26-33)...

Column 1 - ACRES - planted acres for each crop. MISC is assumed to be specialty vegetables (same as VEGETABLE). FALLOW ground is assumed to have a Kc of .06 all year (following Ayers, 90). TOMATOES includes both canning and market. ALMOND-STONE includes almonds and stonefruit. WALNUT includes walnuts and apples. All acreages are as reported by the Districts, either on their annual reports to the Bureau of Reclamation or other sources. Districts derive their figures from crop reports from the individual Growers and do not exactly verify all reports. Total acreages per year may be more than the District total acreage due to double-cropping.

Column 2 - ETc UNADJUSTED - crop ETc = Kc * ETo. ETo (reference ET of a lush, well-watered, grass pasture) for 1983 through 1989 is taken from CIMIS Station #7 at Telles Ranch. ETo's for 1981 and 1982 were estimated using long-term average ETo at Station #7. Kc's are derived from UC Extension Leaflets 21427 and 21428 modified for local conditions and planting dates. Note that some crop seasonal ETc's will vary greatly depending on planting and harvest dates. This is especially important with specialty vegetables (lettuce, squash, peppers), melons, and tomatoes, which may be planted/harvested plus/minus 3-4 months depending on market conditions/processing contract/management decisions. Average conditions for each District were assumed as much as possible. The monthly Kc's and resulting monthly ETc's for years 1981-1989 are seen in the Appendix DE.

Column 3 - Kc ADJ FACTOR - this is a reduction factor that accounts for bare spots and stunted crop growth (ETc below standard) within fields. Aerial photographs from the entire area for June, 1984 and June, 1989 were analyzed subjectively. A scale of 1-5 was used to estimate both distribution uniformity of the crop (5 being 100% uniform cover) and the amount of bare spots (5 being no bare spots). 772 fields were studied from 1984 and 906 for 1989. The resulting average scalers were then derated by 1/2 for the bareness estimate and by 2/3 for the crop uniformity. For example, if the average bareness scaler was 4, the derated scaler would be 4.5 (5 - (5-4)*.5); and if the average uniformity scaler was 4, the derated scaler would be 4.67 (5 - (5-4)*.33).

The derated scalers were then multiplied together and converted to a percentage for the final adjustment factor. Continuing the example, if the bareness scaler is 4.5 and the uniformity scaler is 4.67, the combined adjustment factor would be 84% (100 x 4.5/5 x 4.67/5). Note that District Irrigation Efficiencies were calculated with and without considering this factor.

Column 4 - ETc ADJUSTED - column 3 * column 2

Column 5 - EFFECTIVE PPT - CIMIS Station #7 is acknowledged to provide incorrect rainfall data. Annual gross PPT was taken from USBR records at Mendota Dam. Corrections for effective PPT were made based on USBR guidelines for cropped and fallow ground (Burt et al, 89). Refer to the discussion under <u>Calculation of Effective Rainfall</u> above for an example of the calculations.

Column 6 - NET EXTERNAL GW CONTRIBUTION - crops can utilize shallow groundwater for a significant portion of annual ETc (studies show from 20-60% for deep-rooted crops). Column 6 is an estimate of how much groundwater utilization is from groundwater <u>originating outside of the District</u>. There is considerable disagreement over how much lateral sub-surface flow occurs. Results from studies of the San Joaquin Valley Drainage Program show that the sub-surface hydrogeology of the area is complex. All four Districts are at lower elevations than surrounding Districts. Panoche Water District estimates that there is a "background flow" (flow that will occur regardless of irrigation in the District) of some 15 cfs from its tile drains. Broadview Water District claims that 27% of its pumped drainage originates from surrounding Districts. The notes in the individual District s will describe the actual numbers used. There is a question as to whether all crops/fields in a District are affected by a high water table. In the case of Broadview it was assumed that all land was affected. For Firebaugh, Panoche, and Pacheco, calculations of District Irrigation Efficiency were done with and without considering upwards movement of GW (see columns 26-33 in Table DE-9).

Column 7 - NET LEACHING - leaching water required to maintain a salt balance sufficient to allow for 100% yield with the most sensitive crop in the rotation (standard is canning tomatoes, yield threshold at 2.5 dS/m). The idea is that the Grower should manage the soil, not the crop, for salinity control. Refer to the Appendix "Leaching Requirement Summary" for explanations of the actual calculations. The calculations also required an estimate of irrigation water quality. Quality reported as parts-per-million Total Dissolved Solids were converted to dS/m by dividing by 650.

Column 8 - NET WATER REQUIREMENTS UNADJUSTED ETc = ETc UNADJUSTED + NET LEACHING - EFFECTIVE PPT - NET EXTERNAL GW CONTRIBUTION (column 2 + column 7 -

column 5 - column 6) - this is the net water required for application by the District farmers assuming 100% crop ETc on the entire District acreage.

Column 9 - NET WATER REQUIREMENTS ADJUSTED ETc = ETc ADJUSTED + NET LEACHING - EFFECTIVE PPT - NET EXTERNAL GW CONTRIBUTION (column 4 + column 7 - column 5 - column 6) - this is the net water required for application by the District farmers assuming crop ETc adjusted for stunted growth and/or bare spots in individual fields.

Column 10 - RECLAMATION LEACHING - the individual District may have been in a reclamation mode (more salts being removed from the District than being brought in) during some years. This is an estimate of how much applied water could be considered reclamation leaching. Note that District Irrigation Efficiencies in the Broadview Water District summaries are calculated with and without considering this factor.

Column 11 - WATER REQUIREMENTS with RECLAMATION and UNADJUSTED ETc = ETc UNADJUSTED + NET LEACHING + RECLAMATION LEACHING - EFFECTIVE PPT - NET EXTERNAL GW CONTRIBUTION (column 2 + column 7 + column 10 - column 5 - column 6) - this is the net water required for application by the District farmers assuming 100 % crop ETc, normal leaching requirements, and reclamation leaching.

Column 11a - WATER REQUIREMENTS with UNADJUSTED ETc but no contribution from groundwater = ETc UNADJUSTED + NET LEACHING - EFFECTIVE PPT (column 2 + column 7 - column 5) - this is the net water required for application by the District farmers assuming 100 % crop ETc and normal leaching requirements and no upwards contribution from groundwater. (Reclamation leaching was not considered because this column was used only for Firebaugh Canal, Panoche, and Pacheco Water Districts, none of which are in a reclamation mode.)

Column 12 - WATER REQUIREMENTS with RECLAMATION and ADJUSTED ETc = ETc UNADJUSTED + NET LEACHING + RECLAMATION LEACHING - EFFECTIVE PPT - NET EXTERNAL GW CONTRIBUTION (column 4 + column 7 + column 10 - column 5 - column 6) - this is the net water required for application by the District farmers assuming adjusted crop ETc's, normal leaching requirements, and reclamation leaching.

TABLE DE-6 - 1985 Data for Broadview Water District

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	345	3.40	1.000	3.40	3.44	0.00	-0.00	0.00	0.00	2.97	2.93	2.93
MISC	150	16.72	0.876	14.65	3.86	0.00	0.73	13.59	11.52	2.97	16.56	14.49
COTTON	4037	27.83	0.876	24.38	3.46	1.39	1.39	24.37	20.91	2.97	27.34	23.89
ALFALFA	150	55.59	0.876	48.70	5.00	2.78	2.89	50.70	43.81	2.97	53.67	46.78
WHEAT	983	17.91	0.876	15.69	4.16	0.45	0.78	14.09	11.87	2.97	17.06	14.84
MELONS	790	14.01	0.876	12.27	3.53	0.35	0.60	10.72	8.99	2.97	13.70	11.96
TOMATOES	750	27.58	0.876	24.16	3.53	1.38	1.37	24.04	20.62	2.97	27.01	23.59
SUGARBEET	750	38.38	0.876	33.62	3.89	1.92	1.97	34.53	29.78	2.97	37.51	32.75
BARLEY	425	15.24	0.876	13.35	4.16	0.38	0.63	11.33	9.44	2.97	14.30	12.41
BEANS	0	21.12	0.876	18.50	3.46	0.53	1.01	18.14	15.52	2.97	21.11	18.49
SD ALFALFA	630	38.43	0.876	33.67	4.19	1.92	1.95	34.27	29.51	2.97	37.25	32.48
RICE	0	43.82	0.876	38.39	3.84	2.19	2.28	40.06	34.63	2.97	43.04	37.60
CORN	0	28.48	0.876	24.95	3.46	0.71	1.43	25.73	22.20	2.97	28.70	25.17
VEGETABLE	0	16.72	0.876	14.65	3.86	0.00	0.73	13.59	11.52	2.97	16.56	14.49
PASTURE	0	50.99	0.876	44.67	5.00	2.55	2.62	46.07	39.75	2.97	49.04	42.72
ALMOND-STONE	0	44.34	0.876	38.84	4.09	2.22	2.30	40.33	34.83	2.97	43.30	37.80
WALNUT	0	54.80	0.876	48.01	4.17	2.74	2.89	50.78	43.99	2.97	53.76	46.96
MILO	0	24.37	0.876	21.35	3.46	0.61	1.19	21.49	18.47	2.97	24.46	21.44

TABLE DE-7 - BWD Two-Year Moving Average District Irrigation Efficiencies

TWO-YEAR MOVING AVERAGE EFFICIENCIES		13	14	15	16	17	18	19	20	21	22	23	24	25
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY	PUMPED SUPPLY	TOTAL CONTROL. SUPPLY	OTHER SURFACE	TOTAL AVAIL. SUPPLY	UNADJ ETc NO RECL / FIRM	UNADJ ETc + RECL / FIRM	UNADJ ETc NO RECL / AVAIL	UNADJ ETc + RECL / AVAIL	ADJ ETc NO RECL / FIRM	ADJ ETc + RECL / FIRM	ADJ ETc NO RECL / AVAIL	ADJ ETc + RECL / AVAIL
		Ac-Ft	Ac-Ft	Ac-Ft	Ac-Ft	Ac-Ft	%	%	%	%	%	%	%	%
1981-1982	18187	30820	0	30820	9400	40220	97	97	89	89	97	97	77	77
1982-1983	18462	32676	0	32676	9400	42076	83	87	65	68	72	75	56	58
1983-1984	18355	41387	0	41387	9400	50787	67	75	55	61	57	64	46	52
1984-1985	18065	50052	0	50052	8617	58669	72	81	62	69	62	70	53	60
1985-1986	18033	43582	0	43582	7050	50632	72	83	62	71	61	72	53	62
1986-1987	18021	34108	0	34108	5483	39591	82	97	71	83	70	84	60	72
1987-1988	18265	33774	0	33774	3350	37124	86	97	78	89	73	85	66	77
1988-1989	18285	38749	0	38749	1500	40249	84	94	81	91	73	82	70	79

TABLE DE-8 - 1985 Data for Firebaugh Canal Water District

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	0	3.40	1.000	3.40	3.44	0.00	-0.00	0.00	0.00	0.00	0.00	0.00
MISC	0	16.72	0.876	14.65	3.86	0.00	0.61	13.47	11.39	0.00	13.47	11.39
COTTON	10699	27.83	0.876	24.38	3.46	1.39	1.15	24.13	20.68	0.00	25.52	22.07
ALFALFA	992	55.59	0.876	48.70	5.00	2.78	2.39	50.21	43.31	0.00	52.98	46.09
WHEAT	2941	17.91	0.876	15.69	4.16	0.45	0.65	13.95	11.73	0.00	14.40	12.18
MELONS	942	14.01	0.876	12.27	3.53	0.35	0.50	10.62	8.89	0.00	10.97	9.24
TOMATOES	0	27.58	0.876	24.16	3.53	1.38	1.14	23.81	20.39	0.00	25.19	21.77
SUGARBEET	2759	38.38	0.876	33.62	3.89	1.92	1.63	34.20	29.44	0.00	36.12	31.36
BARLEY	0	15.24	0.876	13.35	4.16	0.38	0.52	11.22	9.33	0.00	11.60	9.71
BEANS	0	21.12	0.876	18.50	3.46	0.53	0.84	17.97	15.35	0.00	18.49	15.88
SD ALFALFA	0	38.43	0.876	33.67	4.19	1.92	1.62	33.94	29.18	0.00	35.86	31.10
RICE	649	43.82	0.876	38.39	3.84	2.19	1.89	39.67	34.24	0.00	41.87	36.43
CORN	0	28.48	0.876	24.95	3.46	0.71	1.18	25.49	21.95	0.00	26.20	22.67
VEGETABLE	749	16.72	0.876	14.65	3.86	0.00	0.61	13.47	11.39	0.00	13.47	11.39
PASTURE	0	50.99	0.876	44.67	5.00	2.55	2.18	45.62	39.30	0.00	48.17	41.85
ALMOND-STONE	0	44.34	0.876	38.84	4.09	2.22	1.90	39.94	34.44	0.00	42.15	36.66
WALNUT	0	54.80	0.876	48.01	4.17	2.74	2.39	50.29	43.50	0.00	53.03	46.24
MILO	0	24.37	0.876	21.35	3.46	0.61	0.99	21.28	18.26	0.00	21.89	18.87

TABLE DE-9 - FCWD Two-Year Moving Average District Irrigation Efficiencies

TWO-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc -GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc -GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc -GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc -GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1982-1983	37028	100538	0	100538	0	100538	64	68	64	68	53	57	53	57
1983-1984	37475	109883	0	109883	0	109883	67	71	67	71	56	60	56	60
1984-1985	40422	127326	0	127326	0	127326	67	71	67	71	57	61	57	61
1985-1986	39556	110398	0	110398	0	110398	71	75	71	75	60	64	60	64
1986-1987	40766	110099	0	110099	0	110099	73	77	73	77	62	66	62	66

Column 12a - WATER REQUIREMENTS with ADJUSTED ETc but no contribution from groundwater = ETc UNADJUSTED + NET LEACHING - EFFECTIVE PPT (column 4 + column 7 - column 5) - this is the net water required for application by the District farmers assuming adjusted crop ETc and normal leaching requirements and no upwards contribution from groundwater. (Reclamation leaching was not considered because this column was used only for Firebaugh Canal, Panoche, and Pacheco Water Districts, none of which are in a reclamation mode.)

Column 13 - SURFACE SUPPLY - total water deliveries through the Delta-Mendota and/or San Luis (California Aqueduct) Canals. There were two main sources for these numbers: District delivery records and Bureau of Reclamation records. Errors are present in both. Water meters on the Delta-Mendota are old and are scheduled for replacement soon. However, deliveries to Growers are either measured with District meters, which can get clogged with weeds, algae, or other debris or need repair also, or with weirs and gates where canal water levels can vary with time. Also, some Districts charge for transportation losses and some do not. In some cases there were significant differences between the BurRec and District records.

Column 14 - PUMPED SUPPLY - estimate of Grower/District pumping. There was no significant Grower groundwater pumping in any of the Districts until the 1989 season.

Column 15 - TOTAL CONTROLLABLE SUPPLY - the amount of supply controlled by the Grower or District = column 13 + column 14

Column 16 - OTHER SURFACE - an estimate of useable surface inflow from other sources outside the District (significant in the case of Broadview Water District)

Column 17 - TOTAL AVAILABLE SUPPLY - the total available water supply = column 13 + column 14 + column 16

Columns 18 - 33 - IRRIGATION EFFICIENCY - District Irrigation Efficiency is defined as the beneficial use (ET and salt balance/reclamation leaching) of applied water <u>within the District</u> divided by the total water applied at the surface (irrigation/effective PPT/GW). Note that columns 8, 9, 11, and 12 are multiplied by the appropriate crop acreages and summed so that seasonal IE is a division of beneficially used acre-feet by applied acre-feet. Specifically...

column 18 = column 8 / column 15
column 19 = column 9 / column 15

column 20 = column 8 / column 17
column 21 = column 9 / column 17
column 22 = column 11 / column 15
column 23 = column 12 / column 15
column 24 = column 11 / column 17
column 25 = column 12 / column 17
column 26 = column 8 / column 15
column 27 = column 11a / column 15
column 28 = column 8 / column 17
column 29 = column 11a / column 17
column 30 = column 9 / column 15
column 31 = column 12a / column 15
column 32 = column 9 / column 17
column 33 = column 12a / column 17

Because of the problems in accurately estimating the different components of the water balance, some of the calculations could result in a number higher than 100%. Assuming a minimum 3% evaporation loss, a limit of 97% was placed on the District Irrigation Efficiencies.

The eight IE's calculated for Broadview Water District (columns 18 - 25 of Table DE-7) consider the eight different combinations of adjusted/unadjusted ETc, with and without reclamation leaching, and with and without uncontrolled surface inflows to the District. Column 22 would be the most restrictive definition in that it uses adjusted crop ETc (the lower of adjusted or unadjusted), with no allowance for beneficial reclamation leaching, divided by the total available water supply (including an estimate of surface inflow from surrounding lands). Columns 18 and 19 would be the most "traditional" definitions in that unadjusted ETc's (assumed 100% ETc over total acreage) are used, with and without beneficial reclamation leaching (only significant in Broadview Water District), divided by the firm water supply.

There were also eight irrigation efficiencies calculated for the other three Districts (columns 26-33 in Table DE-9). They considered adjusted/unadjusted ETc's, firm and available water supplies, and whether or not there was upwards flow from shallow groundwater. Columns 32 and 33 are considered the most accurate but choosing between them (or some weighted average) depends on the true extent of groundwater influence. Columns 26 and 27 would be the most "traditional" definition as it uses unadjusted ETc's and only the firm water supply numbers.

INDIVIDUAL DISTRICT CONSIDERATIONS

Broadview Water District (BWD)

The summaries for BWD are seen in Tables DE-10, DE-11, and DE-12 (individual crop year information for years 1981 to 1989 are seen in the Appendix DE). Table DE-10 is a summary using single-year numbers. Table DE-11 is a summary using two-year moving averages. Table DE-12 is a summary using three-year moving averages. Tables DE-11 and DE-12 are felt to be better estimates of overall District IE due to overlapping crop and water years.

Specific notes for BWD are...

Column 1 - ACRES - taken from BWD's Drainage Operation Plan (DOP) submitted to the Central Valley Regional Water Quality Control Board December 14, 1989. 1989 numbers are preliminary data.

Column 3 - Kc ADJUSTMENT factor - this is an estimate based on a subjective analysis of aerial photographs for stunted growth and bare spots in individual fields.

Column 5 - EFFECTIVE PPT - An average 2 in/ft AWHC was used for the BWD soils. Refer to the previous Calculation of Effective Rainfall explaining the derivation of effective PPT's for crop root zones.

Column 6 - NET EXTERNAL GROUNDWATER CONTRIBUTION - BWD has been affected by a high water table for some time and 6500 acres of the District have tiled drains installed (BWD DOP, 1989). This column only considers that utilized groundwater coming in from outside sources. BWD cites studies showing 27% (25% was used in the calculations) of the pumped drainage from BWD is from external sources. Column 6 is calculated as...

$$GW = ETc * GW_{ext} * GW_{ETc}$$

where: GW = contribution to crop ETc from groundwater originating outside the District (NET EXTERNAL..., column 6)

ETc = unadjusted annual crop ETc (column 2)

GW_{ETc} = % of ETc that will come from groundwater = 20 for deep-rooted crops such as cotton, alfalfa, and tomatoes, 10% for shallower, 0 for shallow-rooted crops

GW_{ext} = % of GW originating from outside the District = 25

thus...

$GW = ETc * .2 * .25 = .05 * ETc$ (for a deep-rooted crop like cotton)

Column 7 - NET LEACHING - applied water in excess of crop ETc needed to maintain a soil salt level sufficient to support the most sensitive crop in the rotation (tomatoes at 2.5 dS/m). The actual number depends on the quality of delivered water. Average delivered water quality was taken from BWD's Drainage Operation Plan (DOP) (see BWD, 1989). (See the Appendix "Leaching Requirements Summary" for details.)

Column 10 - RECLAMATION LEACHING - in 1983 BWD negotiated an agreement with the Grasslands Water District that allowed BWD to transport up to 25 CFS of pumped drainage (plus another 10 CFS of Delta-Mendota Canal water as required) through Grasslands channels to the San Joaquin River. The agreement specified water quality standards. Up to that time, BWD soils were slowly salting up. Subsequent to the 1983 agreement, BWD entered a reclamation mode where excess salts in the soil were leached out. In BWD's DOP, the total drainage leaving BWD was seen to go from 15,772 acre-feet in 1984 down to 9,062 acre-feet in 1989. Also in the DOP was four years of data (1986-1989) for total collected sub-surface water. To determine column 10, column 7 was first multiplied by the acreage of each crop and divided by 12. This would be the required AF application to maintain a salt balance. Column 7 was summed and subtracted from the collected drainage as reported by BWD's DOP (the four year average from 1986-1989 was used for years 1983-1984 (tile drain water collection had been estimated at 3500 acre-feet, see Nelson, 1984). The results were multiplied by 75%, to account for drainage originating from outside the District. The resulting drain volume was divided by the cropped acreage. The acre-inch/acre result is considered reclamation leaching. It was assumed that all acreage in BWD was in a reclamation mode.

Example: For 1986, each crop's ACRE (column 1) was multiplied by the NET LEACHING (column 7) and the results summed as NET_LECH (884 acre-feet). BWD reports 4626 acre-feet total collected tile drain water in 1986, call it DRAIN. Thus potential reclamation drainage is...

$$DRAIN_{rec} = DRAIN - NET\_LECH = 4626 - 865 = 3761 \text{ acre-feet}$$

Further, BWD estimates 25% of pumped drainage to be from sub-surface inflow from upslope drainers. Thus...

$$DRAIN_{rec} = DRAIN_{rec} * .75 = 3761 * .75 = 2821 \text{ acre-feet}$$

and reclamation leaching on an average acre-inch/acre basis is....

$$REC\_LEACH = 12 * DRAIN_{rec} / 9023 = 3.75 \text{ acre-inch/acre}$$

This method of determining REC_LEACH assumes that any deep percolation from irrigation applications is picked up by BWD's tile drain system. This is possibly incorrect but any other assumption would require more information, which is unavailable at this time, concerning sub-surface flows into and out of BWD.

Column 13 - SURFACE SUPPLY - the two sources for this number differed considerably. One source was BWD's Drainage Operation Plan (see BWD, 1989) but those values had to be estimated from a line graph. Statements were (BWD, 1991 and PANWD, 1991) that the Bureau's meters are old and sometimes are inoperable (in which case the BurRec uses BWD estimates). The Bureau of Reclamation records for deliveries were used.

Column 16 - OTHER SURFACE - BWD takes drainage from an area upslope of the District in the Firebaugh Drainage Association. This was reported to be as much as 8000 acres early in the 80's but may be as low as 3500 acres now. Flow was estimated at 4700 acre-feet annually in January 1984 (Nelson, 1984). This flow and drained acreage has steadily decreased since and was very little in the last two years due to the drought (BWD, 1991).

TABLE DE-10 - BWD Single-Year District Irrigation Efficiencies

		13	14	15	16	17	18	19	20	21	22	23	24	25
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc NO RECL / FIRM %	UNADJ ETc + RECL / FIRM %	UNADJ ETc NO RECL / AVAIL %	UNADJ ETc + RECL / AVAIL %	ADJ ETc NO RECL / FIRM %	ADJ ETc + RECL / FIRM %	ADJ ETc NO RECL / AVAIL %	ADJ ETc + RECL / AVAIL %
1981	9025	15645	0	15645	4700	20345	97	97	83	83	93	93	71	71
1982	9162	15175	0	15175	4700	19875	97	97	95	95	97	97	84	84
1983	9300	17501	0	17501	4700	22201	48	54	37	43	39	45	31	36
1984	9055	23886	0	23886	4700	28586	81	89	68	75	70	78	58	65
1985	9010	26166	0	26166	3917	30083	64	72	56	63	55	63	48	55
1986	9023	17416	0	17416	3133	20549	83	97	71	84	71	86	60	73
1987	8998	16692	0	16692	2350	19042	82	94	72	83	69	82	61	72
1988	9267	17082	0	17082	1000	18082	90	97	85	95	77	88	73	83
1989	9018	21667	0	21667	500	22167	80	89	78	87	69	78	68	76

TABLE DE-11 - BWD Two-Year Moving Average District Irrigation Efficiencies

TWO-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	18	19	20	21	22	23	24	25
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc NO RECL / FIRM %	UNADJ ETc + RECL / FIRM %	UNADJ ETc NO RECL / AVAIL %	UNADJ ETc + RECL / AVAIL %	ADJ ETc NO RECL / FIRM %	ADJ ETc + RECL / FIRM %	ADJ ETc NO RECL / AVAIL %	ADJ ETc + RECL / AVAIL %
1981-1982	18187	30820	0	30820	9400	40220	97	97	89	89	97	97	77	77
1982-1983	18462	32676	0	32676	9400	42076	83	87	65	68	72	75	56	58
1983-1984	18355	41387	0	41387	9400	50787	67	75	55	61	57	64	46	52
1984-1985	18065	50052	0	50052	8617	58669	72	81	62	69	62	70	53	60
1985-1986	18033	43582	0	43582	7050	50632	72	83	62	71	61	72	53	62
1986-1987	18021	34108	0	34108	5483	39591	82	97	71	83	70	84	60	72
1987-1988	18265	33774	0	33774	3350	37124	86	97	78	89	73	85	66	77
1988-1989	18285	38749	0	38749	1500	40249	84	94	81	91	73	82	70	79

TABLE DE-12 - BWD Three-Year Moving Average District Irrigation Efficiencies

THREE-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	18	19	20	21	22	23	24	25
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc NO RECL / FIRM %	UNADJ ETc + RECL / FIRM %	UNADJ ETc NO RECL / AVAIL %	UNADJ ETc + RECL / AVAIL %	ADJ ETc NO RECL / FIRM %	ADJ ETc + RECL / FIRM %	ADJ ETc NO RECL / AVAIL %	ADJ ETc + RECL / AVAIL %
1981-1983	27487	48321	0	48321	14100	62421	91	94	71	73	78	81	61	63
1982-1984	27517	56562	0	56562	14100	70662	82	88	66	70	71	76	57	61
1983-1985	27365	67553	0	67553	13317	80870	66	74	55	62	56	64	47	53
1984-1986	27088	67468	0	67468	11750	79218	75	85	64	73	64	74	55	63
1985-1987	27031	60274	0	60274	9400	69674	74	86	64	75	63	75	55	65
1986-1988	27288	51190	0	51190	6483	57673	85	97	75	87	72	85	64	76
1987-1989	27283	55441	0	55441	3850	59291	84	94	78	88	72	82	67	77

Firebaugh Canal Water District (FCWD)

The summaries for FCWD are seen in Tables DE-13, DE-14, and DE-15 (individual crop year information for years 1982 to 1989 are seen in the Appendix DE). Table DE-13 is a summary using single-year numbers. Table DE-14 is a summary using two-year moving averages. DE-15 is a summary using three-year moving averages. Tables DE-14 and DE-15 are felt to be better estimates of overall District IE due to overlapping crop and water years.

Specific notes for FCWD are...

Column 1 - ACRES - taken from data submitted by FCWD (Camp, 1991) to this project.

Column 5 - EFFECTIVE PPT - An average 2.0 in/ft AWHC for the FCWD soils. Refer to the previous Calculation of Effective Rainfall explaining the derivation of effective PPT's for crop root zones.

Column 6 - NET EXTERNAL GROUNDWATER CONTRIBUTION - Well over 50% of FCWD is tiled (FCWD, 1985) and crop utilization of GW is significant in this area. This column only considers that utilized groundwater coming in from outside sources. The San Joaquin Valley Drainage Program (SJVDP) and others estimate that up to 20% of crop ETc can be supplied by a high water table. Thus Column 6 is calculated as...

$$GW = ETc * GW_{ext} * GW_{ETc}$$

where: GW = contribution to crop ETc from groundwater originating outside the District (NET EXTERNAL..., column 6)

ETc = unadjusted annual crop ETc (column 2)

GW_{ETc} = % of ETc that will come from groundwater = 20 for deep-rooted crops such as cotton, alfalfa, and tomatoes, 10% for shallower, 0 for shallow-rooted crops

GW_{ext} = % of GW originating from outside the District = 25

thus...

$$GW = ETc * .2 * .25 = .05 * ETc \text{ (for a deep-rooted crop like cotton)}$$

Column 7 - NET LEACHING - applied water in excess of crop ETc needed to maintain a soil salt level sufficient to support the most sensitive crop in the rotation (tomatoes at 2.5 dS/m). The actual number depends on the quality of delivered water. FCWD water comes from the Delta-Mendota Canal (DMC). BWD's DOP (see BWD, 1990) shows a 7 year average of 288 ppm TDS. However, DMC water quality has declined in recent years due to the drought and increased diversions through the Sacramento/San Joaquin Delta. 350 ppm TDS was used for the calculation of column 7.

Column 10 - RECLAMATION LEACHING - FCWD has not been in a reclamation mode.

Columns 11a and 12a - because there is some question as to the extent of District lands affected by upwards groundwater flow, irrigation efficiencies were calculated with and without column 6.

Column 13 - SURFACE SUPPLY - the two sources for this number differed considerably. The Bureau of Reclamation's Delta-Mendota Canal dumps into the Mendota Pool where water is delivered to four Districts (FCWD, Central California ID, Columbia Canal Company, and San Luis Canal Company) under a single contract. The split among the four is an internal agreement. The Bureau of Reclamation may check FCWD's main intake weir periodically. FCWD's Manager states that some FCWD reported water deliveries would be water accounted for twice as there are some tailwater systems in the District and field tailwater will go back into the District's supply for use by other Growers. Also, although significant only since 1990, some pumped drainage has been recycled if water quality is sufficiently good. (FCWD does not monitor pumped drainage flows.) FCWD numbers were used with the caution that a small portion is double counted.

Column 16 - OTHER SURFACE - FCWD does not accept surface tailwater from any upslope drainers.

TABLE DE-13 - FCWD Single-Year District Irrigation Efficiencies

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc -GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc -GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc -GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc -GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1982	20244	54529	0	54529	0	54529	65	69	65	69	54	58	54	58
1983	16784	46009	0	46009	0	46009	63	67	63	67	51	55	51	55
1984	20691	63874	0	63874	0	63874	70	73	70	73	60	63	60	63
1985	19731	63452	0	63452	0	63452	64	68	64	68	55	58	55	58
1986	19825	46946	0	46946	0	46946	80	84	80	84	68	72	68	72
1987	20941	63153	0	63153	0	63153	67	71	67	71	57	61	57	61
1988	23282	70265	0	70265	0	70265	67	71	67	71	58	61	58	61
1989	24746	65976	0	65976	0	65976	82	86	82	86	70	75	70	75

TABLE DE-14 - FCWD Two-Year Moving Average District Irrigation Efficiencies

TWO-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc -GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc -GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc -GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc -GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1982-1983	37028	100538	0	100538	0	100538	64	68	64	68	53	57	53	57
1983-1984	37475	109883	0	109883	0	109883	67	71	67	71	56	60	56	60
1984-1985	40422	127326	0	127326	0	127326	67	71	67	71	57	61	57	61
1985-1986	39556	110398	0	110398	0	110398	71	75	71	75	60	64	60	64
1986-1987	40766	110099	0	110099	0	110099	73	77	73	77	62	66	62	66
1987-1988	44223	133418	0	133418	0	133418	67	71	67	71	57	61	57	61
1988-1989	48028	136241	0	136241	0	136241	74	78	74	78	64	68	64	68

TABLE DE-15 - FCWD Three-Year Moving Average District Irrigation Efficiencies

THREE-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc -GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc -GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc -GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc -GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1982-1984	57719	164412	0	164412	0	164412	66	70	66	70	55	59	55	59
1983-1985	57206	173335	0	173335	0	173335	66	70	66	70	56	59	56	59
1984-1986	60247	174272	0	174272	0	174272	70	74	70	74	60	64	60	64
1985-1987	60497	173551	0	173551	0	173551	70	73	70	73	59	63	59	63
1986-1988	64048	180364	0	180364	0	180364	71	75	71	75	60	64	60	64
1987-1989	68969	199394	0	199394	0	199394	72	76	72	76	62	66	62	66

Panoche Water District (PANWD)

The summaries for PANWD are seen in Tables DE-16, DE-17, and DE-18 (individual crop year information for years 1984 to 1989 are seen in the Appendix DE). Table DE-16 is a summary using single-year numbers. Table DE-17 is a summary using two-year moving averages. Table DE-18 is a summary using three-year moving averages. Tables DE-17 and DE-18 are felt to be better estimates of overall District IE due to overlapping crop and water years.

Specific notes for PANWD are...

Column 1 - ACRES - taken from PANWD reports to the Bureau of Reclamation.

Column 3 - Kc ADJUSTMENT factor - this is an estimate based on a subjective analysis of aerial photographs for stunted growth and bare spots in individual fields.

Column 5 - EFFECTIVE PPT - SCS soil surveys were used to estimate an average 2.0 in/ft AWHC for the PANWD soils. Refer to the previous Calculation of Effective Rainfall explaining the derivation of effective PPT's for crop root zones.

Column 6 - NET EXTERNAL GROUNDWATER CONTRIBUTION - Over 50% of PANWD has installed tile drains (see Hoffman, 1988) and crop utilization of GW is significant in parts of PANWD. This column only considers that utilized groundwater coming in from outside sources. PANWD's DOP (PANWD, 1989) indicates at least 700 acre-feet per month as a "background" flow from their tile systems (water collected regardless of PANWD irrigation). Assuming an average 30,000 acre-feet per year total collected indicates approximately 25% of the high groundwater in PANWD to be coming from outside the District. The SJVDP and others estimate that up to 20% of crop ETc can be supplied by a high water table. Thus Column 6 is calculated as...

$$GW = ETc * GW_{ext} * GW_{ETc}$$

where: GW = contribution to crop ETc from groundwater originating outside the District (NET EXTERNAL..., column 6)

ETc = unadjusted annual crop ETc (column 2)

GW_{ETc} = % of ETc that will come from groundwater = 20 for deep-rooted crops such as cotton, alfalfa, and tomatoes, 10% for shallower, 0 for shallow-rooted crops

GW_{ext} = % of GW originating from outside the District = 25

thus...

GW = ETc * .2 * .25 = .05 * ETc (for a deep-rooted crop like cotton)

Column 7 - NET LEACHING - applied water in excess of crop ETc needed to maintain a soil salt level sufficient to support the most sensitive crop in the rotation (tomatoes at 2.5 dS/m). The actual number depends on the quality of delivered water. PANWD water comes from the Delta-Mendota Canal (DMC). BWD's DOP (see BWD, 1989) shows a 7 year average of 288 ppm TDS. However, DMC water quality has declined in recent years due to the drought and increased diversions through the Sacramento/San Joaquin Delta. 350 ppm TDS was used for the calculation of column 7.

Column 10 - RECLAMATION LEACHING - PANWD is not in a reclamation mode.

Columns 11a and 12a - because there is some question as to the extent of District lands affected by upwards groundwater flow, irrigation efficiencies were calculated with and without column 6.

Column 13 - SURFACE SUPPLY - the two sources for this number did not differ greatly. The Bureau of Reclamation records for deliveries were used.

Column 16 - OTHER SURFACE - PANWD does not take any surface tailwater from upslope drainers.

TABLE DE-16 - Panoche WD Single-Year District Irrrigation Efficiencies

SINGLE YEAR EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc - GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc - GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc - GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc - GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1984	34244	101911	0	101911	0	101911	65	68	65	68	55	59	55	59
1985	34244	91804	0	91804	0	91804	70	73	70	73	59	63	59	63
1986	34621	100001	0	100001	0	100001	61	64	61	64	52	55	52	55
1987	33006	96944	0	96944	0	96944	64	67	64	67	54	58	54	58
1988	34647	92702	0	92702	0	92702	73	77	73	77	63	67	63	67
1989	36715	91869	3000	94869	0	94869	78	82	78	82	67	71	67	71

TABLE DE-17 - Panoche WD Two-Year Moving Average District Irrigation Efficiencies

TWO-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc - GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc - GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc - GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc - GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1984-1985	68488	193715	0	193715	0	193715	67	70	67	70	57	61	57	61
1985-1986	68865	191805	0	191805	0	191805	65	69	65	69	55	59	55	59
1986-1987	67627	196945	0	196945	0	196945	62	66	62	66	53	56	53	56
1987-1988	67653	189646	0	189646	0	189646	68	72	68	72	58	62	58	62
1988-1989	71362	184571	0	184571	0	184571	77	81	77	81	66	70	66	70

TABLE DE-18 - Panoche WD Three-Year Moving Average District Irrigation Efficiencies

THREE-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc - GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc - GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc - GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc - GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1984-1986	103109	293716	0	293716	0	293716	65	68	65	68	55	59	55	59
1985-1987	101871	288749	0	288749	0	288749	65	68	65	68	55	58	55	58
1986-1988	102274	289647	0	289647	0	289647	66	70	66	70	56	60	56	60
1987-1989	104368	281515	0	281515	0	281515	72	76	72	76	62	66	62	66

Pacheco Water District (PACWD)

The summaries for PACWD are seen in Tables DE-19, DE-20, and DE-21 (individual crop year information for years 1984 to 1989 are seen in the Appendix DE). Table DE-19 is a summary using single-year numbers. Table DE-20 is a summary using two-year moving averages. Table DE-21 is a summary using three-year moving averages. Tables DE-20 and DE-21 are felt to be better estimates of overall District IE due to overlapping crop and water years.

Specific notes for PACWD are...

Column 1 - ACRES - taken from PACWD reports to the Bureau of Reclamation.

Column 3 - Kc ADJUSTMENT factor - this is an estimate based on a subjective analysis of aerial photographs for stunted growth and bare spots in individual fields.

Column 5 - EFFECTIVE PPT - SCS soil surveys were used to estimate an average 2.0 in/ft AWHC for the PACWD soils. Refer to the previous Calculation of Effective Rainfall explaining the derivation of effective PPT's for crop root zones. Due to the availability of some rainfall records at Pacheco, effective PPT as calculated using Mendota Dam rainfall was derated by 10%.

Column 6 - NET EXTERNAL GROUNDWATER CONTRIBUTION - A large part of PACWD has installed tile drains. Monthly drainage discharge records provided in PACWD's Drainage Operation Plan (see PACWD, 1990) indicate a very small "background" flow (tile drainage pumped regardless of Pacheco Water District irrigations), possibly as low as 30-40 acre-feet per month. This column only considers that utilized groundwater coming in from outside sources. The SJVDP and others estimate that up to 20% of crop ETc can be supplied by a high water table. Thus Column 6 is calculated as...

$$GW = ETc * GW_{ext} * GW_{ETc}$$

where: GW = contribution to crop ETc from groundwater originating outside the District (NET EXTERNAL..., column 6)

ETc = unadjusted annual crop ETc (column 2)

GW_{ETc} = % of ETc that will come from groundwater = 20 for deep-rooted crops such as cotton, alfalfa, and tomatoes, 10% for shallower, 0 for shallow-rooted crops

GW_{ext} = % of GW originating from outside the District = 25

thus...

GW = ETc * .2 * .25 = .05 * ETc (for a deep-rooted crop like cotton)

Column 7 - NET LEACHING - applied water in excess of crop ETc needed to maintain a soil salt level sufficient to support the most sensitive crop in the rotation (tomatoes at 2.5 dS/m). The actual number depends on the quality of delivered water. PACWD water comes from the Delta-Mendota Canal (DMC), either directly or as pumped water from Central California Irrigation District's Outside Canal (DMC water also). BWD's DOP (see BWD, 1990) shows a 7 year average of 288 ppm TDS. However, DMC water quality has declined in recent years due to the drought and increased diversions through the Sacramento/San Joaquin Delta. 350 ppm TDS was used for the calculation of column 7.

Column 10 - RECLAMATION LEACHING - PACWD is not in a reclamation mode.

Columns 11a and 12a - because there is some question as to the extent of District lands affected by upwards groundwater flow, irrigation efficiencies were calculated with and without column 6.

Column 13 - SURFACE SUPPLY - the two sources for this number differed considerably. PACWD's supply comes from a Federal Contract and an agreement with Central California Irrigation District. Except for 1988 (which was an incomplete data set), PACWD's records were used.

Column 16 - OTHER SURFACE - PACWD does not take any surface tailwater from upslope drainers.

TABLE DE-19 - Pacheco WD Single-Year District Irrigation Efficiencies

SINGLE YEAR EFFICIENCIES		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc - GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc - GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc - GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc - GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1984	4318	10775	0	10775	0	10775	76	80	76	80	66	70	66	70
1985	4220	11337	0	11337	0	11337	52	55	52	55	45	48	45	48
1986	4013	11542	0	11542	0	11542	47	49	47	49	39	42	39	42
1987	4400	12987	0	12987	0	12987	50	53	50	53	43	45	43	45
1988	4360	10872	0	10872	0	10872	62	65	62	65	53	56	53	56
1989	4144	13063	0	13063	0	13063	52	55	52	55	45	47	45	47

TABLE DE-20 - Pacheco WD Two-Year Moving Average District Irrigation Efficiencies

TWO-YEAR MOVING AVERAGE EFFICIENCIES		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc - GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc - GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc - GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc - GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1984-1985	8538	22112	0	22112	0	22112	64	67	64	67	55	58	55	58
1985-1986	8233	22879	0	22879	0	22879	49	52	49	52	42	45	42	45
1986-1987	8413	24529	0	24529	0	24529	48	51	48	51	41	44	41	44
1987-1988	8760	23859	0	23859	0	23859	55	58	55	58	47	50	47	50
1988-1989	8504	23935	0	23935	0	23935	56	59	56	59	48	51	48	51

TABLE DE-21 - Pacheco WD Three-Year Moving Average District Irrigation Efficiencies

THREE-YEAR MOVING AVERAGE EFFICIENCIES

		13	14	15	16	17	26	27	28	29	30	31	32	33
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY Ac-Ft	PUMPED SUPPLY Ac-Ft	TOTAL CONTROL. SUPPLY Ac-Ft	OTHER SURFACE Ac-Ft	TOTAL AVAIL. SUPPLY Ac-Ft	UNADJ ETc - GrndWat / FIRM %	UNADJ ETc NO GW / FIRM %	UNADJ ETc - GrndWat / AVAIL %	UNADJ ETc NO GW / AVAIL %	ADJ ETc - GrndWat / FIRM %	ADJ ETc NO GW / FIRM %	ADJ ETc - GrndWat / AVAIL %	ADJ ETc NO GW / AVAIL %
1984-1986	12551	33654	0	33654	0	33654	58	61	58	61	50	53	50	53
1985-1987	12633	35866	0	35866	0	35866	50	52	50	52	42	45	42	45
1986-1988	12773	35401	0	35401	0	35401	53	55	53	55	45	48	45	48
1987-1989	12904	36922	0	36922	0	36922	54	57	54	57	46	49	46	49

Discussion of Procedure

To explain the procedure better, while pointing out the areas of possible error, Figure DE-1 is repeated below.

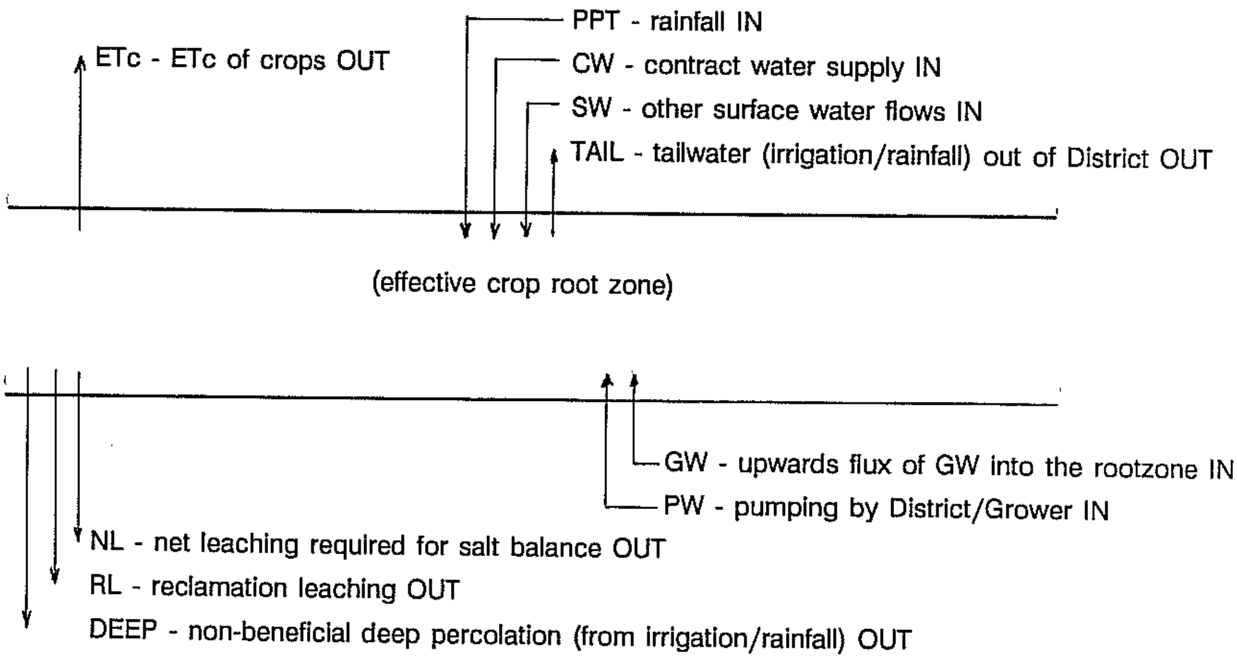

Figure DE-2 - Schematic of District Water Balance

Again, the definition of District Irrigation Efficiency (DIE) is the total beneficial use of applied irrigation water <u>within District boundaries</u> divided by the total applied irrigation water. To better understand the limitations of this study, the development of the equation used to calculate DIE is described below. The equation evolved in a series of steps of increasing complexity. And, each step resulted in a more correct equation.

An evolutionary development of the calculation of DIE would start with the two basic components, crop water use (ETc) and the contract water supply (CW). (All components are in net acre-feet.) Thus...

$$DIE_1 = ETc / CW$$

However, maintaining a salt balance in the soil is essential for longterm production. The beneficial use must also include net leaching requirements (NL). Thus...

$$DIE_2 = (ETc + NL) / CW$$

It is important to note here that NL is a calculated value, just as ETc is a calculated value. It is what is estimated to potentially be used beneficially.

On the supply side, it is clear that applied water should also include any pumped groundwater (PW) and also any incidental surface water coming into the District that is used (SW). Thus...

$$DIE_3 = (ETc + NL) / (CW + PW + SW)$$

Assuming for the moment that the District is not in a reclamation mode, effective rainfall (EFF_PPT) will be that rain that infiltrates into the soil and helps satisfies crop ETc or the net maintenance leaching requirements. Thus...

$$DIE_4 = (ETc + NL - EFF\_PPT) / (CW + PW + SW)$$

It is also clear from research that crops will utilize water from a shallow water table (GW). Thus...

$$DIE_5 = (ETc + NL - EFF\_PPT - GW) / (CW + PW + SW)$$

Again referring to the Figure DE-1, the only components not considered in the equation are DEEP and TAIL. But assuming the District is not in a reclamation mode, this is not important. The definition of DIE evaluates only beneficial use. DEEP and TAIL are non-beneficial. Any DEEP and TAIL may be reused by other Districts, but that is not the concern of this study. However, the values of DEEP and TAIL, if known, would serve as a check on the computations.

A major question arises if it is assumed that the District is in a reclamation mode, as is assumed to be the case with Broadview Water District (BWD). BWD reports being in a substantially net positive salt balance ever since the District negotiated its drainage outlet. To accurately model the BWD water balance should require an estimate of how much DEEP is beneficial reclamation leaching (RL). Now...

$$DIE_6 = (ETc + NL + RL - EFF\_PPT - GW) / (CW + PW + SW)$$

Now that RL is to be considered, there are two problems. First, an estimate of DEEP must be made, which implies an evaluation of TAIL at the same time. Second, with total DEEP estimated, how much of it is beneficial reclamation leaching? If BWD soil was (and is) substantially saline, then all DEEP could be considered beneficial. Again, in contrast to the uncertainties in estimating RL, remember that net maintenance leaching requirements for salt balance (NL) are calculated values based on an accepted rationale that considers delivered irrigation water quality (a measured value) and yield limiting soil salinity limits (from research) (see Appendix, "Net Leaching Requirements").

The reader is cautioned to understand the limitations of this project. The model of the water balance is considered accurate. One limitation is that some of the component estimates may have a confidence level of plus/minus 10%, or more (as in unadjusted crop ETc's). But a second problem is deciding which components need to be evaluated. Is the District in a reclamation mode or not? Is there significant upwards flux from shallow groundwater, supplied from groundwater originating outside the District?

Because of this question of significant components, eight different calculations of DIE were made for each District. In Broadview's case, the significant question is to what extent it is in a reclamation mode. Thus four DIE's were calculated assuming beneficial reclamation leaching and four without. For the other three Districts, there was a question as to the validity of using upwards flux of groundwater. Thus for these Districts four estimates of DIE were made assuming an upwards flux and four without.

One of the objectives of this project was to evaluate the adequacy of available information. As just discussed, much of the data needed to calculate District Irrigation Efficiencies is hard to get and/or of suspect accuracy. To put the situation in perspective, the individual columns in the District spreadsheets were rated considering three attributes, accuracy, importance, and ease of acquisition. A scale of 1 to 5 was used to categorize each attribute of each column. A rating of 5 would be highest accuracy, highest importance, or easiest to acquire. A rating of 1 would be lowest accuracy, lowest importance, or hardest to acquire.

Thus a best case rating is 5-5-5 (in accuracy-importance-ease of acquisition order), very accurate, very important, and easy to get. Another best case could be 5-1-5, accurate and easy to get, and just not important. A worst case would be 1-5-1, not very accurate, but very important, and hard to get. The ratings for selected columns were...

Column 1 - ACRES - planted acres for each crop - 4-5-5 - crop acreages are reported but not checked; cropped acreage is a direct impact on IE's; reports are made to the BurRec and there are also District reports

Column 2 - ETc UNADJUSTED - unadjusted crop evapotranspiration - 3.5-5-5 - there is enough research literature available to be +/- 10% (maybe 5) easily if the planting/harvest dates are known; ETc's are the largest water use in the equation for IE's; standardized weather information is available from CIMIS, crop coefficients from the UC

Column 3 - Kc ADJ FACTOR - the adjusting factor for reducing overall crop ETc's due to uniformity and bare spots - 2.5-5-3 - the accuracy of the adjusting factor is dependent on the method and there is no standard objective method for such large-scale applications; the adjustment factor is a direct impact if using adjusted ETc's in the calculation for IE's; difficult to get enough information to make an estimate, even with aerials, would be very expensive on ground

Column 5 - EFFECTIVE PPT - amount of rainfall that infiltrates and is beneficial for ETc or leaching requirements - 3-4-4 - have to use average conditions to judge infiltration, rainfall is variable from field to field, impact dependent on soil moisture and condition, slopes, etc; only about 10-30% of ETc is satisfied by rainfall so +/- 10% variance in estimates is a small impact on the final District IE's; CIMIS weather stations available but rainfall highly variable, also depends on leaching requirements calculation, maximum use in off-season

Column 6 - NET EXTERNAL GW CONTRIBUTION - upwards flow into root zone from shallow groundwater, constrained to groundwater originating outside the District - 2-4-2 - have to use average conditions, the hydrogeology is complex; same (or less) impact as rainfall; estimates from researchers of crop utilization vary widely, regardless of where the groundwater originates

Column 7 - NET LEACHING - leaching required to maintain a salt balance - 4-3-4 - dependent on accurate reports of delivered water quality and effective PPT estimate, also the yield threshold of most sensitive crop; same (or less) impact as rainfall (most NL's with Delta-Mendota Canal water below 3"); need delivered water quality which can be difficult to estimate in situations with recycling or substantial use of deep wells

Column 10 - RECLAMATION LEACHING - leaching to remove excess salts - 2-(1-5)-2 - have to back into this most of time, little or no information on sub-surface lateral flows; could be significant in cases like BWD but most Districts are short of water and not reclaiming land anymore

Column 13 - SURFACE SUPPLY - contract water delivered to the District - 4-5-5 - accuracy dependent on meter conditions; a direct impact on calculated IE's; there are records for canal deliveries <u>but probably not on a field-by-field basis</u>

Column 14 - PUMPED SUPPLY - pumped groundwater - 3-(1-5)-3 - many well meters are not installed correctly (and many don't have meters) and rarely maintained (especially with private growers); depending on the mix of surface and groundwater used for irrigation it is a direct impact on calculations; may have to access utility records for power and efficiency tests

Column 16 - OTHER SURFACE - tailwater running into the District and used by Growers - 1-(1-5)-3 - this is probably not metered at all; it may or may not be significant depending on District; probably need to talk to someone (individual Growers that are using it) that sees it every day

<u>Sensitivity Analysis</u>
"Irrigation Water Use in the Central Valley of California" was released by the Central Valley Water Use Study Committee in the mid-80's. In the <u>Data and Research Needs</u> (p 42) they state "The actual amount of water applied to a farm, an irrigation district, or hydrologic area is very difficult to estimate accurately. This difficulty is due to unavailable or inaccurate records of the amount of water delivered from surface supplies and pumped from groundwater." Further, "Although estimates of applied water evapotranspired by crops were judged to be reasonable, this use is the largest component of water in agriculture. Small errors in these estimates could result in substantial amounts of water unaccounted for in water balances for individual DAUs [detailed analysis units]." Their statements were seen to be true today also.

Reviewing the <u>Discussion of Procedure</u> above, it is clear that it is difficult if not impossible to accurately identify many of the components of the District water balance. In consideration of this inaccuracy, an additional analysis was performed to see how far the calculations of District Irrigation Efficiency would vary if the estimates were changed. Two analyses were done using 1986-1988 data for Broadview Water District. One was done with estimates for beneficial use of water increased and available water decreased, which would result in higher IE values. The following changes were made...

- ETc UNADJUSTED were increased 10%
- ETc-ADJ adjustment factors were increased by 5%
- Effective rainfall was decreased 10%
- net external GW use was decreased to 50% of original estimates
- reclamation leaching was increased 10%
- other surface supplies were reduced 10%

TABLE DE-23a - Broadview Water District 1986 Data - Original Estimates

1986 DATA

0.67 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
4626 AF = COLLECTED TILE DRAINAGE

55.46 inches = ANNUAL ETo
6.81 inches = ANNUAL PPT
3.75 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	854	3.33	1.000	3.33	4.27	0.00	-0.06	0.00	0.00	3.75	2.69	2.69
MISC	140	15.56	0.876	13.63	5.36	0.00	0.61	10.82	8.89	3.75	14.57	12.64
COTTON	4231	26.99	0.876	23.64	4.57	1.35	1.35	22.42	19.07	3.75	26.17	22.82
ALFALFA	147	54.20	0.876	47.48	5.77	2.71	2.91	48.63	41.91	3.75	52.38	45.66
WHEAT	968	16.76	0.876	14.68	5.41	0.42	0.68	11.61	9.53	3.75	15.36	13.28
MELONS	670	13.32	0.876	11.66	4.65	0.33	0.55	8.89	7.23	3.75	12.64	10.99
TOMATOES	750	26.66	0.876	23.36	4.65	1.33	1.32	22.01	18.70	3.75	25.76	22.45
SUGARBEET	425	36.74	0.876	32.18	5.36	1.84	1.88	31.42	26.87	3.75	35.18	30.62
BARLEY	113	14.31	0.876	12.54	5.41	0.36	0.53	9.08	7.30	3.75	12.83	11.05
BEANS	20	20.17	0.876	17.67	4.39	0.50	0.95	16.22	13.72	3.75	19.98	17.47
SD ALFALFA	705	36.58	0.876	32.05	5.41	1.83	1.87	31.21	26.67	3.75	34.96	30.43
RICE	0	41.88	0.876	36.69	4.97	2.09	2.22	37.03	31.84	3.75	40.78	35.59
CORN	0	27.56	0.876	24.15	4.57	0.69	1.38	23.68	20.27	3.75	27.44	24.02
VEGETABLE	0	15.56	0.876	13.63	5.36	0.00	0.61	10.82	8.89	3.75	14.57	12.64
PASTURE	0	49.91	0.876	43.72	5.77	2.50	2.65	44.30	38.11	3.75	48.05	41.86
ALMOND-STONE	0	42.69	0.876	37.40	5.15	2.13	2.25	37.66	32.37	3.75	41.41	36.12
WALNUT	0	53.15	0.876	46.56	5.15	2.66	2.88	48.23	41.63	3.75	51.98	45.39
MILO	0	23.64	0.876	20.71	4.57	0.59	1.14	19.62	16.69	3.75	23.37	20.44

TABLE DE-23b - BWD 1986, 1986-1987, and 1986-1988 District Efficiencies

		13	14	15	16	17	18	19	20	21	22	23	24	25
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY	PUMPED SUPPLY	TOTAL CONTROL. SUPPLY	OTHER SURFACE	TOTAL AVAIL. SUPPLY	UNADJ ETc NO RECL / FIRM	UNADJ ETc + RECL / FIRM	UNADJ ETc NO RECL / AVAIL	UNADJ ETc + RECL / AVAIL	ADJ ETc NO RECL / FIRM	ADJ ETc + RECL / FIRM	ADJ ETc NO RECL / AVAIL	ADJ ETc + RECL / AVAIL
		Ac-Ft	Ac-Ft	Ac-Ft	Ac-Ft	Ac-Ft	%	%	%	%	%	%	%	%
1986	9023	17416	0	17416	3133	20549	83	97	71	84	71	86	60	73
1986-1987	18021	34108	0	34108	5483	39591	82	97	71	83	70	84	60	72
1986-1988	27288	51190	0	51190	6483	57673	85	97	75	87	72	85	64	76

TABLE DE-24a - Broadview Water District 1986 Data - Estimates Varied to INcrease DIE
ETc x 1.1; ADJ=.926; EFF_PPT x .9; Rec Leach x 1.1; GW x 1.5; OTHER x .9

1986 DATA

0.67 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
4626 AF = COLLECTED TILE DRAINAGE

55.46 inches = ANNUAL ETo
6.81 inches = ANNUAL PPT
3.64 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	854	3.66	1.000	3.66	3.86	0.00	-0.04	0.00	0.00	4.01	3.73	3.73
MISC	140	17.12	0.926	15.85	4.82	0.00	0.71	13.00	11.74	4.01	17.01	15.74
COTTON	4231	29.69	0.926	27.49	4.11	0.74	1.51	26.34	24.14	4.01	30.35	28.15
ALFALFA	147	59.62	0.926	55.21	5.19	1.49	3.23	56.17	51.76	4.01	60.18	55.77
WHEAT	968	18.44	0.926	17.07	4.87	0.23	0.78	14.11	12.75	4.01	18.12	16.76
MELONS	670	14.65	0.926	13.56	4.18	0.18	0.63	10.91	9.83	4.01	14.92	13.84
TOMATOES	750	29.33	0.926	27.16	4.18	0.73	1.48	25.90	23.73	4.01	29.91	27.74
SUGARBEET	425	40.41	0.926	37.42	4.82	1.01	2.10	36.68	33.69	4.01	40.69	37.70
BARLEY	113	15.75	0.926	14.58	4.87	0.20	0.62	11.30	10.13	4.01	15.30	14.14
BEANS	20	22.19	0.926	20.55	3.95	0.28	1.07	19.03	17.39	4.01	23.04	21.40
SD ALFALFA	705	40.24	0.926	37.26	4.87	1.01	2.09	36.45	33.48	4.01	40.46	37.48
RICE	0	46.07	0.926	42.66	4.47	1.15	2.47	42.91	39.50	4.01	46.92	43.51
CORN	0	30.32	0.926	28.08	4.11	0.38	1.55	27.37	25.13	4.01	31.38	29.14
VEGETABLE	0	17.12	0.926	15.85	4.82	0.00	0.71	13.00	11.74	4.01	17.01	15.74
PASTURE	0	54.91	0.926	50.84	5.19	1.37	2.95	51.29	47.23	4.01	55.30	51.24
ALMOND-STONE	0	46.96	0.926	43.49	4.64	1.17	2.51	43.66	40.19	4.01	47.67	44.20
WALNUT	0	58.47	0.926	54.14	4.64	1.46	3.20	55.57	51.24	4.01	59.58	55.25
MILO	0	26.00	0.926	24.08	4.11	0.33	1.29	22.85	20.92	4.01	26.86	24.93

TABLE DE-24b - BWD 1986, 1986-1987, and 1986-1988 District Efficiencies w/ Varied Estimates

		13	14	15	16	17	18	19	20	21	22	23	24	25
							IRRIGATION EFFICIENCY							
YEAR	ACRES	SURFACE SUPPLY	PUMPED SUPPLY	TOTAL CONTROL. SUPPLY	OTHER SURFACE	TOTAL AVAIL. SUPPLY	UNADJ ETc NO RECL / FIRM	UNADJ ETc + RECL / FIRM	UNADJ ETc NO RECL / AVAIL	UNADJ ETc + RECL / AVAIL	ADJ ETc NO RECL / FIRM	ADJ ETc + RECL / FIRM	ADJ ETc NO RECL / AVAIL	ADJ ETc + RECL / AVAIL
		Ac-Ft	Ac-Ft	Ac-Ft	Ac-Ft	Ac-Ft	%	%	%	%	%	%	%	%
1986	9023	17416	0	17416	2828	20244	97	97	84	97	90	97	77	92
1986-1987	18021	34108	0	34108	4943	39051	97	97	85	97	89	97	78	91
1986-1988	27288	51190	0	51190	5843	57033	97	97	90	97	92	97	82	95

TABLE DE-25a - Broadview Water District 1986 Data - Estimates Varied to Decrease DIE
ETc x .9; ADJ at .826; EFF-PPT x 1.1; Rec Leach x .9; GW x .5; OTHER x 1.1

1986 DATA

0.67 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
4626 AF = COLLECTED TILE DRAINAGE

55.46 inches = ANNUAL ETo
6.81 inches = ANNUAL PPT
3.86 inches = REC LEACHING

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11 WATER REQ W/ REC UNADJUST. ETc In	12 WATER REQ W/ REC ADJUST. ETc In
FALLOW	854	2.99	1.000	2.99	4.68	0.00	-0.08	0.00	0.00	3.47	1.62	1.62
MISC	140	14.01	0.826	11.57	5.90	0.00	0.52	8.63	6.19	3.47	12.10	9.67
COTTON	4231	24.29	0.826	20.06	5.03	1.82	1.18	18.62	14.40	3.47	22.10	17.87
ALFALFA	147	48.78	0.826	40.29	6.35	3.66	2.58	41.36	32.87	3.47	44.83	36.34
WHEAT	968	15.08	0.826	12.46	5.96	0.57	0.58	9.14	6.52	3.47	12.62	9.99
MELONS	670	11.98	0.826	9.90	5.10	0.45	0.47	6.90	4.82	3.47	10.37	8.28
TOMATOES	750	24.00	0.826	19.82	5.11	1.80	1.16	18.25	14.07	3.47	21.72	17.55
SUGARBEET	425	33.06	0.826	27.31	5.90	2.48	1.66	26.35	20.60	3.47	29.82	24.07
BARLEY	113	12.88	0.826	10.64	5.96	0.48	0.45	6.89	4.65	3.47	10.36	8.12
BEANS	20	18.16	0.826	15.00	4.83	0.68	0.83	13.47	10.31	3.47	16.94	13.78
SD ALFALFA	705	32.93	0.826	27.20	5.96	2.47	1.65	26.15	20.42	3.47	29.63	23.90
RICE	0	37.69	0.826	31.13	5.47	2.83	1.96	31.36	24.80	3.47	34.83	28.28
CORN	0	24.81	0.826	20.49	5.03	0.93	1.21	20.06	15.75	3.47	23.54	19.22
VEGETABLE	0	14.01	0.826	11.57	5.90	0.00	0.52	8.63	6.19	3.47	12.10	9.67
PASTURE	0	44.92	0.826	37.11	6.35	3.37	2.35	37.56	29.74	3.47	41.03	33.21
ALMOND-STONE	0	38.42	0.826	31.74	5.67	2.88	2.00	31.87	25.19	3.47	35.35	28.66
WALNUT	0	47.84	0.826	39.51	5.67	3.59	2.56	41.15	32.82	3.47	44.62	36.30
MILO	0	21.27	0.826	17.57	5.03	0.80	1.00	16.45	12.75	3.47	19.92	16.22

TABLE DE-25b - BWD 1986, 1986-1987, and 1986-1988 District Efficiencies

YEAR	ACRES	13 SURFACE SUPPLY Ac-Ft	14 PUMPED SUPPLY Ac-Ft	15 TOTAL CONTROL. SUPPLY Ac-Ft	16 OTHER SURFACE Ac-Ft	17 TOTAL AVAIL. SUPPLY Ac-Ft	18 IRRIGATION EFFICIENCY UNADJ ETc NO RECL / FIRM %	19 UNADJ ETc + RECL / FIRM %	20 UNADJ ETc NO RECL / AVAIL %	21 UNADJ ETc + RECL / AVAIL %	22 ADJ ETc NO RECL / FIRM %	23 ADJ ETc + RECL / FIRM %	24 ADJ ETc NO RECL / AVAIL %	25 ADJ ETc + RECL / AVAIL %
1986	9023	17416	0	17416	3446	20862	69	83	57	69	53	67	44	56
1986-1987	18021	34108	0	34108	6031	40139	68	81	58	69	52	65	44	55
1986-1988	27288	51190	0	51190	7131	58321	71	82	62	72	54	66	48	58

The other additional analysis was with estimates of beneficial water use decreased and the available supply increased, which would result in low IE values. Changes made were...

- crop ETc's were decreased 10%
- ETc-ADJ adjustment factors were decreased by 5%
- effective rainfall was increased 10%
- net external GW use was increased to 1.5 times the original estimate
- reclamation leaching was decreased 10%
- Other surface supplies were increased by 10%

Tables DE-23a and DE-23b show the data and calculated District Irrigation Efficiencies with initial component estimates, Tables DE-24a and DE-24b are the results of increasing beneficial use/decreasing supplies, and Tables DE-25a and DE-25b are the results from decreasing beneficial use/increasing supplies. Table DE-22 below contains sets of the 1986-1988 three year moving averages from these tables, extracted to point out the variance in DIE resulting from the change in component estimates.

Table DE-22 - 1986-1988 Three-Year Moving Average District Irrigation Efficiencies Calculated for Three Different Sets of Component Estimates - for Broadview Water District

Analysis Case	From Column 21 Full ETc, Rec Leach Avail Water	From Column 24 Adj ETc, No Rec Leach Avail Water	From Column 25 Adj ETc, Rec Leach Avail Water
a. Original Component Estimates	87	64	76
b. Component Estimates varied to increase DIE	97	82	95
c. Component Estimates varied to decrease DIE	72	48	58

Looking at Column 25 in Table DE-22 (considered to be the most correct definition for BWD) it is seen that the three-year moving average District Irrigation Efficiency can vary from 58% to 95%, depending on the assumptions.

It is important to differentiate the variance in DIEs due to errors in estimating the water balance components from the variance in DIE's due to using/not using different components in the calculations. For example, looking at Column 21 in Table DE-22, which considers that BWD is in a reclamation mode, uses full ETc, and uses all available irrigation water, the DIE for case a. (using original estimates) is 87%. However, Column 25 assumes an adjusted ETc (adjusting for crop non-uniformity and bare spots) and shows a DIE of 76%.

Further, Column 25, the DIE assuming a reclamation mode, adjusted ETc, and use of all available water, is 76%. But neglecting any beneficial reclamation leaching, as shown in Column 24, results in a DIE of 64%.

To put these 8-11% differences from a definition question in perspective, neglecting beneficial reclamation leaching for 1986 means discounting about 3 acre-inches/acre water. Neglecting the adjustment factor for crop ETc means that estimated cotton ETc goes from 24.2 inches/year to 27.6 inches/year, 3.4 acre-inches/acre.

Discussion of Results

Increases/decreases in District Irrigation Efficiency can be internal reactions to external factors. Figure DE-3 is a graph of DIE versus time for Broadview Water District with three major events marked. Point 1 is for 1983 when BWD finished negotiations for their drainage outlet. It is assumed that the District immediately went into a reclamation mode. Point 2 is also around 1983 and marks a significant crop shift to fallow ground, possibly coinciding with the Payment-In-Kind program (designed to control cotton plantings). Point 3 is the full disclosure of selenium toxicity at Kestersen Refuge.

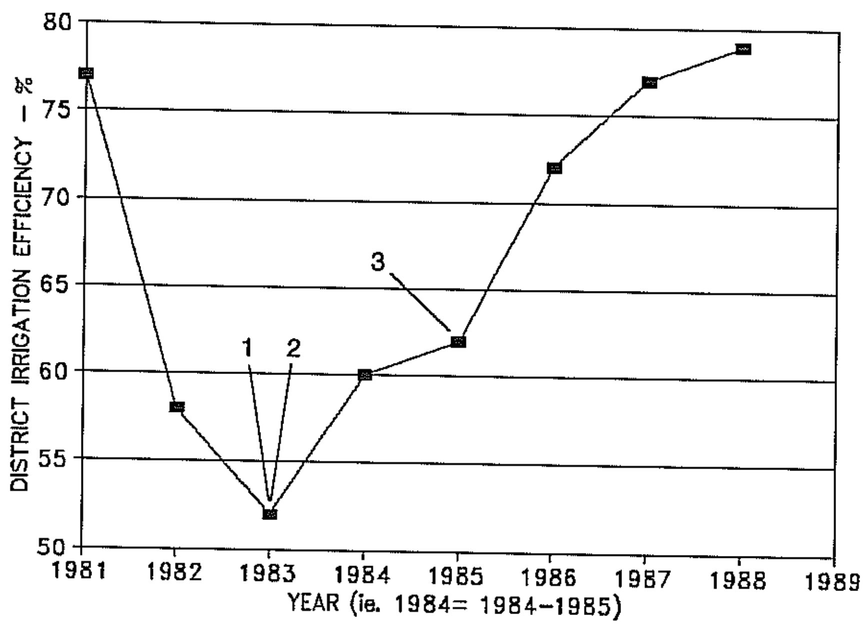

Figure D-3 - Broadview Water District 2-year Moving Average District Irrigation Efficiency (DIE) versus Time

Noting BWD's response at the three points in Figure DE-1, external forces to consider are...

a. costs of drainwater disposal - this could be an increase in "wheeling" charges (charges from another District to use its canals to transport drain water) or the cost of constructing new facilities.

b. restrictions on drainwater disposal - new quality standards in the San Joaquin River will affect District operations to the extent that poor quality drainwater will have to be recycled or diluted.

c. new legislation - there is continued pressure to reform the way water is allocated and priced in Western irrigated agriculture. Any reduction in supply or increase in cost will result in increased efficiency. New legislation may also work to facilitate transfers from rural to urban users. The remaining water could be used more efficiently as Growers try to maintain current cropped acreages.

d. crop mix - depending on the economics of the market place and Government Farm Programs, there may be significant shifts in crop mix within any one District. The Westlands Water District has seen a sharp increase in the acreage for fresh vegetables. They use less water per crop but are generally irrigated less efficiently. Also, an increase in commodity prices could work to allow wider utilization of more expensive irrigation technology, such as drip tape on vegetables and cotton. Conversely, a decrease in commodity prices would discourage increased production costs.

e. law suits - a law suit could work in both ways, depending on who is Plaintiff and who is Defendant. Court decisions may force an increase in efficiency due to a reduction in allocation and/or drainage opportunity. However, before and during a law suit, a District may choose not to make improvements for fear of jeopardize a legal position.

f. technology and technology transfer - there may be some breakthrough in drain water treatment that could ease the pressure for efficiency. Or, continuing efforts by UC Extension, Cal Poly, DWR, and private industry will work to continually increase District efficiency.

g. drought - continued drought in California could force a permanent reallocation of supplies, again forcing an increase in efficiency.

Another question would be, does there have to be an external factor to force the internal response? It is fairly clear that a jump in District Irrigation Efficiency occurred in the 1985-

1987 period. It is assumed that this improvement was a response to the Kestersen situation. Would this improvement have occurred without Kestersen?

How can the District and Grower respond? Changes can be management only, hardware only, or a combination. From a District viewpoint, a pure management response is to institute tiered water pricing. This might be considered a negative or a positive type of approach. It could be negative if considered a penalty for those less efficient, especially if the tier only acts to increase the price of water past the first tier. It can be considered a positive if it acts to reward efficiency by reducing the price of the first tier water.

Another management response is to provide education. The advent of the Water Conservation Coordinator-type position in many Districts, rural or urban, is another common reaction.

A hardware-oriented District response would be to improve the flexibility of water delivery. This might mean partial or full automation of the system or more ditch riders to allow 12-hour on/off notices instead of 48 hour. Also there could be improvements in water measurement and increased ranges of delivery flows.

There might be a question of whether the District responds first or the individual Grower. This depends on the nature of the external pressure as well as the character of the District. It is also a very fine point as the District is run by its Growers. Any change in District policy is from a vote by the Board. It may be a question of whether the member-Growers see changes necessary first at the macro (District) or the micro (on-field) level.

A macro-level response is for a District to prohibit tailwater runoff from farms. The micro-level response from the Growers is to install tailwater reuse systems. (A possible, unforeseen result of such a macro-level response would be an increase in deep percolation as the District maintains current surface delivery schedule policies which do not allow for early shutoffs, thus forcing Growers to put excess delivered water into the ground.)

A change in Government Farm Policy or other marketplace economics would most likely initiate an on-field/Grower response first. The example would be the crop shift due to the PIK program or the shift into vegetables in Westlands.

A reallocation or shortage of contract water could mean a notice from the District informing individual Growers of less available water (again a micro-level), or an aggressive program of education and system modernization to cope with the shortage (macro-level).

Normally, whether the Grower responds first or the District, the other will have to follow suit.

Conclusions

Table DE-26 is a summary of the two-year moving average District Irrigation Efficiencies for the four Districts. There are two sets of data for Broadview Water District (BWD), one considering beneficial reclamation leaching, one without. Column 33 (no consideration of upwards groundwater flux) was used for the other three Districts, Firebaugh Canal (FCWD), Panoche (PANWD), and Pacheco Water Districts (PACWD). In all of the Districts there was an increase in District Irrigation Efficiency through the 1985-1987 period. This is assumed to be a response to the Kestersen situation. Since then there does not seem to be a clear trend towards continued improvement. Data from 1990 and 1991 may show continued increases in DIE but will be affected by the drought.

TABLE DE-26 - Summary of Two-Year Moving Average District Irrigation Efficiencies Using Adjusted Estimated Crop Evapotranspiration

DISTRICT	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989
BWD[1]	60	62	72	77	79
BWD[2]	53	53	60	66	70
FCWD	61	64	66	61	68
PANWD	61	59	56	62	70
PACWD	58	45	44	50	51

[1] assuming beneficial reclamation leaching
[2] assuming no beneficial reclamation leaching

One effect of the drought may well be a reduction in the ETc adjustment factor as Growers stress crops. Another factor might be Growers planting more acreage than prudent, hoping for extra water to appear in mid-season. Without the additional water, some acreage will be abandoned. These abandoned acreages would have to be considered separately if performing further analyses in the same manner as this study.

Broadview is seen to be at a relatively higher DIE level (BWD[1]) than the others if allowing for beneficial reclamation. However, if disregarding beneficial reclamation (BWD[2]) the trend is at a level comparable to Panoche and Firebaugh Canal Water Districts.

Pacheco Water District is the anomaly in that it has an indicated low efficiency and little improvement. However, its Drainage Operation Plan (PACWD, 1989) indicates an annual drainage discharge to be near half of its reported surface supplies, about a full acre-foot/acre. More study is needed in this District to verify some of the numbers used.

The results of this study indicate that the four Districts were able to improve District Irrigation Efficiencies, DIE, once. The question is: can they do it again? The important factors may be a reduction in non-beneficial deep percolation or tailwater. However, another important consideration is whether or not the analysis should use full crop ETc's or adjusted crop ETc's.

TABLE DE-27 - Summary of Two-Year Moving Average District Irrigation Efficiencies Using Unadjusted Estimates for Crop Evapotranspiration

DISTRICT	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989
BWD[1]	69	71	83	89	91
BWD[2]	62	62	71	78	81
FCWD	71	75	77	71	78
PANWD	70	69	66	72	81
PACWD	67	52	51	58	59

[1] assuming beneficial reclamation leaching
[2] assuming no beneficial reclamation leaching

Table DE-27 summarizes the two-year moving averages assuming full, estimated ETc and upwards flux from groundwater. Using full crop ETc's shows very high DIE's (compare to Table DE-26), currently near or over 80%. Using adjusted ETc's reduces efficiencies into the 70% range (see Table DE-26, neglecting reclamation leaching for Broadview). The question would now be: is the 70% range a current economic limit or the real, physical limit? Also, is this limit related to some other factor besides the management of irrigation water?

One true conclusion might be that if the Growers had fully uniform, healthy crops, and fully covered fields, they might be near or at the highest expected efficiency under current standards (Table DE-27). That is, Broadview, Firebaugh Canal, and Panoche Water Districts show DIE's in the high 70's to low 80's using full estimated ETc's.

Adjusting the ETc downwards to account for non-uniformity and bare spots acts to decrease DIE because it decreases beneficial use for the same amount of applied irrigation water. But, even allowing that crop uniformity is variable throughout a field, and that bare spots do exist, there might be nothing a Grower could do about the perceived low DIE. That is, he cannot micro-manage irrigation within a field to prevent or reduce water application to poor or bare spots in any one field.

This would then mean that there are two paths towards increasing DIE. One would be improved irrigation water management- reducing non-beneficial deep percolation and/or tailwater. The other would be a function of increasing total yield/unit-water-applied, improved crop management. With the latter course, the total irrigation water application will not go down. Rather the adjustment factor for ETc (a subjective estimate) will tend towards 100% as the Grower receives the highest yields per unit water applied (with bare spots minimized, crop uniformity maximized).

Bibiliography

Ayars, James E. and G. Schrale. 1990. Irrigation efficiency and regional subsurface drain flow on the west side of the San Joaquin Valley, Submitted to California Department of Water Resources. 120 p.

Broadview Water District. 1989. Drainage Operation Plan. Submitted to California Regional Water Quality Control Board, Central Valley Region. 50 p.

Camp, W. (for FCWD). 1990. untitled - FCWD Grower crop reports 1984-1989. Submitted to this project. 2 p.

Firebaugh Canal Water District. 1990. Drainage Operation Plan. Submitted to California Regional Water Quality Control Board, Central Valley Region. 2 p.

Hoffman, G.J. and G. Schrale. 1988. Management strategies to reduce drainage from irrigated agriculture. Presented at ASAE Winter Meeting, Chicago, Ill, Dec 13-16. 14 p.

Nelson, D. (for BWD). 1984. Information needs from westside water districts. Submitted to California Regional Water Quality Control Board, Central Valley Region.

Pacheco Water District. 1990. Drainage Operation Plan. Submitted to California Regional Water Quality Control Board, Central Valley Region. 8 p.

Panoche Water District. 1989. Drainage Operation Plan. Submitted to California Regional Water Quality Control Board, Central Valley Region. 13 p.

LEACHING REQUIREMENT SUMMARY

LEACHING REQUIREMENT SUMMARY

FEBRUARY, 1991

For the

Central Valley Regional Water Quality Control Board

by

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Leaching Requirement (LR)

Definition of LR.

The Leaching Requirement (LR) is the fraction of infiltrated water which must pass through the root zone (and become deep percolation) to maintain some desirable root zone salinity level.

LR values may vary from .01 to .40, depending upon the crop, irrigation water quality, irrigation frequency, soil type, and climate. The calculation of the LR value is not an exact science. The "LR" value is used in computations to determine the amount of water which must infiltrate at a point:

$$\text{Infiltration needed} = \frac{\text{Soil Moisture Depletion}}{(1 - \text{LR})}$$

Definition of LF

The Leaching Fraction (LF) is the portion of the infiltrated water which actually deep percolates below the root zone. Many, if not most, discussions of leaching assume that irrigation is uniform (ie, DU = 100%), and therefore the assumption is that LF = LR. Actually, the LR is the fraction of infiltrated water which must infiltrate at the point in the field which receives the least amount of water (see Figure 1). In order to determine the water requirement for a whole field, the LF must include water necessary for LR, plus water for non-uniformity (Burt, 1990; Stegman et al., 1981).

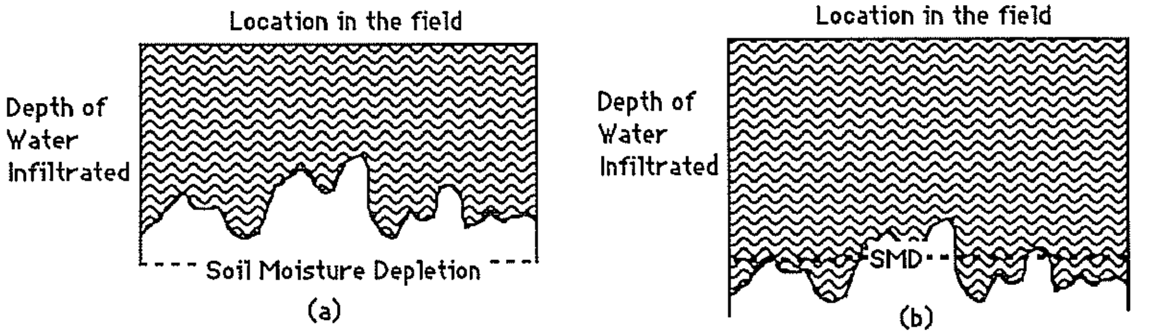

Figure 1. Deep percolation caused by non-uniformity (DU) of irrigation, as affected by under-irrigation. Both (a) and (b) have non-uniformity. However, since (a) is completely under-irrigated, the DU does not contribute to deep percolation. As the under-irrigation is reduced (b), deep percolation due to non-uniformity appears.

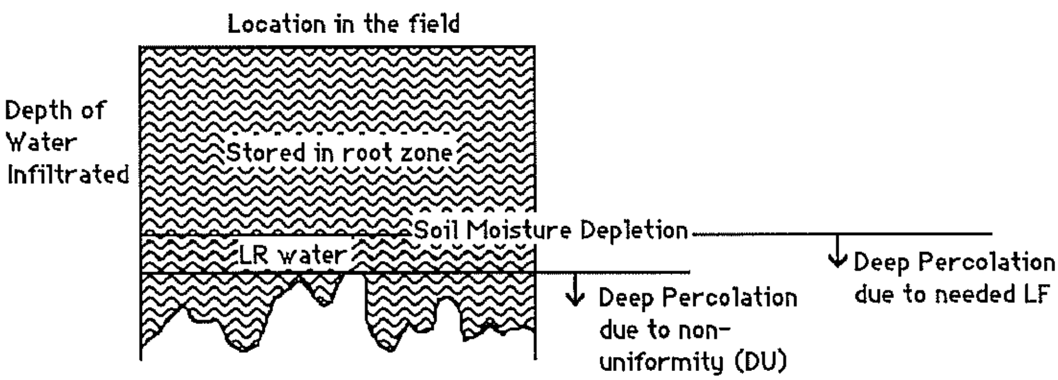

Figure 2. Deep percolation due to LR, LF, and DU. This is a case of "perfect timing" of irrigation, in which enough water has infiltrated at the "driest" point in the field to prevent salt build-up there. LF (Leaching Fraction) accounts for all actual deep percolation, not just the LR.

The minimum LF required on a field is:

$$LF = 1 - [(DU/100)(1-LR)]$$

where DU = Distribution Uniformity of field irrigation, %

The gross irrigation water needed (neglecting evaporation and tailwater runoff) is:

$$\text{Gross needed} = \frac{\text{Net required}}{1 - LF}$$

For questions of required irrigation water, LF should be considered rather than LR.

In this report, some tables contain leaching values in a "net" sense. That is, a net component of water (in units of inches, rather than percentage or fraction) is required to maintain a salt balance at the "critical" point, just as there is an ET (evapotranspiration) requirement at that "critical" point in the field. The designation of "NL" is not a standard abbreviation, but in this report it is equivalent ot:

$$NL = \frac{(ET - \text{Effective Rainfall})}{(1-LR)} - (ET - \text{Effective Rainfall})$$

Conventional Equations for LR.

Many formulas have been used to predict the necessary LR. They generally share the following assumptions:

1. There is no chemical precipitation in the root zone.
2. There is no salt contribution from fertilizers.
3. There is no salt contribution from soil weathering.
4. There is no water uptake from a high water table.
5. The soil wets in a classic fashion during an irrigation; that is, a distinct wetting front moves down from the soil surface.

In this study area, items (1), (3), and (5) are correct. Item (2) is fairly negligible. Item (4) is not true, but in this report it is assumed that the extra leaching water must be applied for the complete ET requirement of the crop (minus effective rainfall), not just the ET requirement which is satisfied by the applied irrigation water on an individual field. In some studies, the LR has only been applied to water which is supplied by irrigation; on some fields which have high water tables the ET contribution from those water tables can be greater than 50%. However, the salinity of those high water tables is generally higher than the irrigation water, and some additional leaching must occur to maintain a net downward flux of salts.

Table 3. Some LR formulas.

Formula (LR =)	Important values	Source
EC_w/EC_{dw}	EC_{dw} = (EC_e at 50% yield reduction) (uniform salinity profile, UP)	Bernstein (1964)
	25% of LR predicted by Bernstein (1964) for low-mod salt tolerance, UP	Bernstein & Francois (1973)
	40% of LR predicted by Bernstein (1964) for salt tolerant crops, UP	Bernstein & Francois (1973)
	EC_{dw} = 2 x (EC_e at 100% yield reduction) (non-uniform profile , NUP)	van Schilfgaarde et al (1974)
	$EC_{dw} = 5\ EC_e - EC_w$ where EC_e is value at 0 % yield decline NUP; logic based on average soil water salinity	Rhoades (1974)
	EC_{dw} = EC_e at 100% yield decline, UP	Ayers (1977)
	EC_{dw} = EC_e of a uniformily salinized root zone w/ 50% crop yield reduction	Bouwer and Idelovitch (1987)
Other	LR depends upon ECw and irrig. frequency	Rhoades and Loveday (1990)

	Leaching Req (LR)	
ECe(threshold)/ECw	High Freq.	Low Freq
1.0	.23	.32
1.25	.13	.22
1.5	.08	.17
1.75	.05	.12
2.0	.03	.10

LR depends upon ECw & linearly-averaged, mean root zone salinity. Shown in the Fig. 4 — Hoffman (1985)

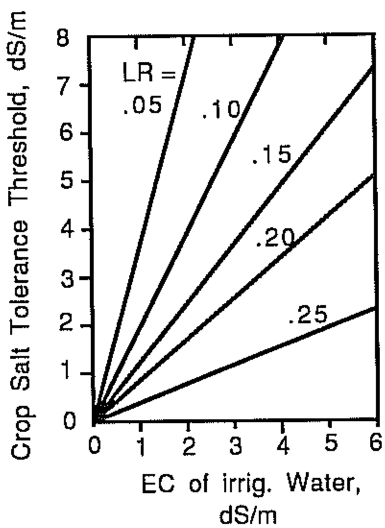

Figure 4. Solution for predicting LR based upon EC_w (Hoffman, 1985)

Hoffman (1985) examined field data from several locations. He then compared the "experimental measured leaching requirement" in those trials which was necessary for no yield reduction, versus the predicted results using various equations. His comparison is shown in the following figure.

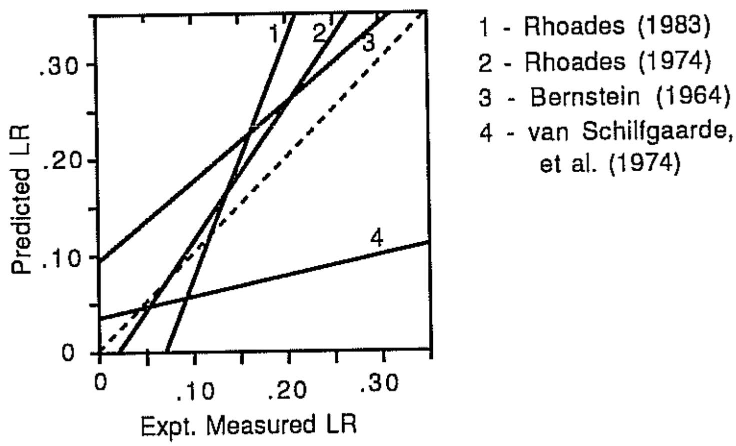

Figure 5. Comparison of LR equations by Hoffman (1985)

The obvious conclusion is that none of the equations precisely predict the limited field results. Furthermore, since each field experiment will provide somewhat different results, it is difficult to know which equation is closest to the "truth". It appears that the equation by Rhoades (1974) most closely matches the field conditions which occur in the Grasslands study area (with a LR of 10-15%)

In other words, the required LR can best be estimated by the equation:

$$LR = \frac{ECw}{5\,ECe - ECw}$$

where ECw = EC of the irrigation water, dS/m
ECe = Threshold ECe of the most sensitive crop to be grown in a rotation on that field. It is based upon the average root zone ECe.

This definition has an important conclusion which is not currently applied in most studies - that the leaching requirements should not be calculated based upon the crops currently planted, but rather, on the most sensitive crops to be grown on the fields. However, studies of soil salinity have long recognized that the LR is an extra fraction of irrigation water applied over a long term (**many years**) to maintain a desirable **soil salinity**.

In the Grasslands study area, tomatoes are in a desirable rotation pattern along with more salt-tolerant crops. It is necessary to irrigate the **soil** with sufficient LR to have a desirable ECe for tomatoes. Therefore, a threshold ECe of 2.5 dS/m was used in calculating the LR, regardless of the actual crop on the field.

References

Ayers, R. S. 1977. Quality of Water for Irrigation. Journal of I&D Engineering, ASCE. 103(2): 135-154.

Bernstein, L. 1964. Salt Tolerance of Plants. U.S. Dept. of Agr. Information Bull. No. 283. Washington, D.C.

Bernstein, L. and L. E. Francois. 1973. Leaching Requirement Studies: Sensitivityof Alfalfa to Salinity of Irrigation and Drainge Waters. Soil Science Soc. Amer. Proc. 37: 931-943.

Bliesner, R. D., R. J. Hanks, L. G. King, and L. S. Willardson. 1977. Effects of Irrigation Management on the Quality of Irrigation Return Flow in Ashley Valley, Utah. Soil Sci. Soc. of Am. Journal. 41: 424-428.

Bouwer, H. and E. Idelovitch. 1987. Quality Requirements for Irrigation with Sewage Water. Journal of I&D Engineering, ASCE. 113(4):516-535.

Burt, C. M. 1990. Efficiency in Irrigation. Presentation to Water District managers at Pardee Reservoir. Oct. 18.

Hoffman, G. J. 1985. Drainage Required to Manage Salinity. Journal of I&D Engineering, ASCE. 111(3): 199-206.

Rhoades, J.D. 1974. Drainage for Salinity Control. Chap. 16 in Drainage for Agriculture. Agronomy Monograph 17. Amer. Soc. of Agronomy. Madison, WI.

Rhoades, J.D. 1983. Reclamation and Management of Salt-Affected Soils After Drainage. From Irrig. Assoc. Short Course on Surface Irrigation, held in Phoenix.

Rhoades, J.D. and J. Loveday. 1990. Salinity in Irrigated Agriculture. Chap. 36 in Irrigation of Agricultural Crops. Agronomy Monograph 30. Amer. Soc. of Agronomy. Madison, WI.

Stegman, E.C., J.T. Musick, and J.I. Stewart. 1981. Irrigation Water Management, Chap 18 in Design and Operation of Farm Irrigation Systems. M. Jensen (ed). Amer. Soc. of Agric. Engr. St. Joseph, MI.

van Schilfgaarde, J., L. Bernstein, J. Rhoades, and S. L. Rawlins. 1974. Irrigation Management for Salt Control. Journal of I&D Engineering, ASCE. 100(3): 321-338.

DISTRICT IRRIGATION EFFICIENCIES APPENDIX

District Irrigation Efficiencies Appendix

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Table A-1 - Alfalfa Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.56	0.64	0.64	0.48	0.55	0.54	0.69	0.74	0.68	0.83
Feb	1	2.06	2.06	1.80	2.16	2.37	2.03	1.71	2.65	1.70
Mar	1	3.92	3.92	3.00	4.60	3.53	3.50	3.78	5.20	3.83
Apr	1	5.72	5.72	4.84	5.77	6.43	5.59	6.65	4.98	5.75
May	1	7.95	7.95	8.80	8.96	7.56	7.50	7.71	7.25	7.86
Jun	1	8.44	8.44	9.57	8.55	8.57	8.04	8.29	7.47	8.58
Jul	1	8.50	8.50	9.24	8.57	8.19	7.90	8.25	8.40	8.95
Aug	1	7.18	7.18	7.48	7.11	7.19	7.30	7.06	6.72	7.40
Sep	1	5.47	5.47	5.73	6.28	5.40	5.07	5.40	5.31	5.12
Oct	1	3.73	3.73	3.45	3.83	3.88	4.02	3.66	3.30	3.94
Nov	0.88	1.59	1.59	1.19	1.54	1.59	2.24	1.43	1.40	1.74
Dec	0.44	0.48	0.48	0.42	0.77	0.34	0.32	0.61	0.41	0.46
Annual		55.67	55.67	55.99	58.68	55.59	54.20	55.29	53.77	56.17

Table A-2 - In-Season Infiltrated Rainfall with Alfalfa (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.41	0.63	2.65	0.09	0.54	0.10	1.00	1.03	0.26
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.33	0.54	0.53	0.50	0.44	0.00	0.75	0.00	0.58
Nov	1.87	1.67	1.00	0.92	2.33	0.00	0.53	0.60	0.28
Dec	0.24	0.90	1.35	2.22	0.87	0.32	1.08	1.77	0.00
Annual	8.39	9.04	11.97	5.48	5.00	5.77	6.91	5.24	4.30

Table A-3 - Off-Season Infiltrated Rainfall with Alfalfa (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A-4 - Barley Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.46	0.53	0.53	0.39	0.45	0.44	0.57	0.61	0.56	0.69
Feb	0.81	1.67	1.67	1.46	1.75	1.92	1.64	1.39	2.15	1.38
Mar	0.99	3.88	3.88	2.97	4.55	3.49	3.47	3.74	5.15	3.79
Apr	0.91	5.20	5.20	4.40	5.25	5.85	5.09	6.05	4.53	5.23
May	0.44	3.50	3.50	3.87	3.94	3.33	3.30	3.39	3.19	3.46
Jun	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.06	0.11	0.11	0.08	0.11	0.11	0.15	0.10	0.10	0.12
Dec	0.13	0.14	0.14	0.12	0.23	0.10	0.09	0.18	0.12	0.14
Annual		15.03	15.03	13.30	16.28	15.24	14.31	15.46	15.79	14.80

Table A-5 - In-Season Infiltrated Rainfall with Barley (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.41	0.63	2.65	0.09	0.54	0.10	1.00	1.03	0.26
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	5.94	5.12	8.40	1.77	1.31	5.13	4.56	2.86	2.26

Table A-6 - Off-Season Infiltrated Rainfall with Barley (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.05	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	1.83	2.36	2.15	2.75	2.86	0.28	1.31	1.76	1.20

Table A-7 - Bean Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.05	0.20	0.20	0.15	0.23	0.18	0.18	0.19	0.26	0.19
Apr	0.15	0.86	0.86	0.73	0.87	0.96	0.84	1.00	0.75	0.86
May	0.69	5.48	5.48	6.07	6.18	5.22	5.18	5.32	5.00	5.42
Jun	1.14	9.62	9.62	10.91	9.75	9.77	9.17	9.45	8.52	9.78
Jul	0.61	5.19	5.19	5.64	5.23	5.00	4.82	5.03	5.12	5.46
Aug	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		21.34	21.34	23.49	22.25	21.12	20.17	20.99	19.65	21.72

Table A-8 - In-Season Infiltrated Rainfall with Beans (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	0.00	0.11	0.41	0.07	0.05	0.11	0.11	0.26	0.08

Table A-9 - Off-Season Infiltrated Rainfall with Beans (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.79	1.09	0.34	0.01	0.06	0.20	0.00	0.68	0.05
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	6.49	5.89	9.05	3.80	3.42	4.28	4.64	3.40	2.41

Table A-10 - Cotton Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.09	0.51	0.51	0.44	0.52	0.58	0.50	0.60	0.45	0.52
May	0.27	2.15	2.15	2.38	2.42	2.04	2.03	2.08	1.96	2.12
Jun	0.72	6.08	6.08	6.89	6.16	6.17	5.79	5.97	5.38	6.18
Jul	1.03	8.76	8.76	9.52	8.83	8.44	8.14	8.50	8.65	9.22
Aug	0.98	7.04	7.04	7.33	6.97	7.05	7.15	6.92	6.59	7.25
Sep	0.58	3.17	3.17	3.32	3.64	3.13	2.94	3.13	3.08	2.97
Oct	0.11	0.41	0.41	0.38	0.42	0.43	0.44	0.40	0.36	0.43
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		28.11	28.11	30.25	28.95	27.83	26.99	27.60	26.46	28.69

Table A-11 - In-Season Infiltrated Rainfall with Cotton (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	0.00	0.81	1.10	0.07	0.05	0.43	0.11	0.26	1.27

Table A-12 - Off-Season Infiltrated Rainfall with Cotton (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.79	1.09	0.34	0.01	0.06	0.20	0.00	0.68	0.05
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	6.49	5.57	8.74	3.80	3.42	4.14	4.64	3.40	1.59

Table A-13 - Corn Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.11	0.63	0.63	0.53	0.63	0.71	0.61	0.73	0.55	0.63
May	0.37	2.94	2.94	3.26	3.32	2.80	2.78	2.85	2.68	2.91
Jun	0.86	7.26	7.26	8.23	7.35	7.37	6.91	7.13	6.42	7.38
Jul	1.1	9.35	9.35	10.16	9.43	9.01	8.69	9.08	9.24	9.85
Aug	0.91	6.53	6.53	6.81	6.47	6.54	6.64	6.42	6.12	6.73
Sep	0.38	2.08	2.08	2.18	2.39	2.05	1.93	2.05	2.02	1.95
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		28.79	28.79	31.17	29.59	28.48	27.56	28.27	27.03	29.44

Table A-14 - In-Season Infiltrated Rainfall with Corn (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	0.00	0.81	1.10	0.07	0.05	0.43	0.11	0.26	1.27

Table A-15 - Off-Season Infiltrated Rainfall with Corn (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.79	1.09	0.34	0.01	0.06	0.20	0.00	0.68	0.05
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	6.49	5.57	8.74	3.80	3.42	4.14	4.64	3.40	1.59

Table A-16 - Fallow Land Crop Coefficients and Monthly/Annual ETc's (in)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.06	0.07	0.07	0.05	0.06	0.06	0.07	0.08	0.07	0.09
Feb	0.06	0.12	0.12	0.11	0.13	0.14	0.12	0.10	0.16	0.10
Mar	0.06	0.24	0.24	0.18	0.28	0.21	0.21	0.23	0.31	0.23
Apr	0.06	0.34	0.34	0.29	0.35	0.39	0.34	0.40	0.30	0.35
May	0.06	0.48	0.48	0.53	0.54	0.45	0.45	0.46	0.44	0.47
Jun	0.06	0.51	0.51	0.57	0.51	0.51	0.48	0.50	0.45	0.51
Jul	0.06	0.51	0.51	0.55	0.51	0.49	0.47	0.50	0.50	0.54
Aug	0.06	0.43	0.43	0.45	0.43	0.43	0.44	0.42	0.40	0.44
Sep	0.06	0.33	0.33	0.34	0.38	0.32	0.30	0.32	0.32	0.31
Oct	0.06	0.22	0.22	0.21	0.23	0.23	0.24	0.22	0.20	0.24
Nov	0.06	0.11	0.11	0.08	0.11	0.11	0.15	0.10	0.10	0.12
Dec	0.06	0.06	0.06	0.06	0.10	0.05	0.04	0.08	0.06	0.06
Annual		3.42	3.42	3.42	3.62	3.40	3.33	3.41	3.30	3.46

Table A-17 - Annual Infiltrated Rainfall with Fallow Land (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.79	1.09	0.34	0.01	0.06	0.20	0.00	0.68	0.05
May	0.00	0.00	0.18	0.00	0.00	0.05	0.05	0.12	0.04
Jun	0.00	0.05	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	6.49	5.93	9.23	3.83	3.44	4.33	4.68	3.52	2.44

Table A-18 - Melon Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.06	0.24	0.24	0.18	0.28	0.21	0.21	0.23	0.31	0.23
Apr	0.18	1.03	1.03	0.87	1.04	1.16	1.01	1.20	0.90	1.04
May	0.46	3.66	3.66	4.05	4.12	3.48	3.45	3.55	3.34	3.62
Jun	0.84	7.09	7.09	8.04	7.18	7.20	6.75	6.96	6.27	7.21
Jul	0.24	2.04	2.04	2.22	2.06	1.97	1.90	1.98	2.02	2.15
Aug	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		14.05	14.05	15.36	14.68	14.01	13.32	13.91	12.83	14.24

Table A-19 - In-Season Infiltrated Rainfall with Melons (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	1.16	1.69	1.16	0.10	0.17	0.57	0.11	1.25	0.20

Table A-20 - Off-Season Infiltrated Rainfall with Melons (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	5.70	4.80	8.72	3.78	3.36	4.08	4.64	2.72	2.35

Table A-21 - Pasture Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.9	1.04	1.04	0.77	0.88	0.86	1.12	1.19	1.09	1.34
Feb	0.9	1.85	1.85	1.62	1.94	2.13	1.83	1.54	2.39	1.53
Mar	0.9	3.53	3.53	2.70	4.14	3.18	3.15	3.40	4.68	3.45
Apr	0.9	5.14	5.14	4.36	5.19	5.79	5.03	5.99	4.48	5.18
May	0.9	7.15	7.15	7.92	8.06	6.80	6.75	6.94	6.53	7.07
Jun	0.9	7.59	7.59	8.61	7.70	7.71	7.24	7.46	6.72	7.72
Jul	0.9	7.65	7.65	8.32	7.71	7.37	7.11	7.43	7.56	8.06
Aug	0.9	6.46	6.46	6.73	6.40	6.47	6.57	6.35	6.05	6.66
Sep	0.9	4.93	4.93	5.16	5.65	4.86	4.56	4.86	4.78	4.61
Oct	0.9	3.35	3.35	3.11	3.45	3.49	3.62	3.29	2.97	3.55
Nov	0.9	1.63	1.63	1.22	1.58	1.63	2.29	1.46	1.43	1.78
Dec	0.9	0.97	0.97	0.86	1.57	0.69	0.66	1.25	0.85	0.95
Annual		51.30	51.30	51.35	54.27	50.99	49.91	51.16	49.52	51.89

Table A-22 - Annual Infiltrated Rainfall with Pasture (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.41	0.63	2.65	0.09	0.54	0.10	1.00	1.03	0.26
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.33	0.54	0.53	0.50	0.44	0.00	0.75	0.00	0.58
Nov	1.87	1.67	1.00	0.92	2.33	0.00	0.53	0.60	0.28
Dec	0.24	0.90	1.35	2.22	0.87	0.32	1.08	1.77	0.00
Annual	8.39	9.04	11.97	5.48	5.00	5.77	6.91	5.24	4.30

Table A-23 - Rice Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.73	2.86	2.86	2.19	3.36	2.58	2.56	2.76	3.80	2.80
Apr	1.1	6.29	6.29	5.32	6.35	7.07	6.15	7.32	5.48	6.33
May	1.16	9.22	9.22	10.21	10.39	8.77	8.70	8.94	8.41	9.12
Jun	1.25	10.55	10.55	11.96	10.69	10.71	10.05	10.36	9.34	10.73
Jul	1.17	9.95	9.95	10.81	10.03	9.58	9.24	9.65	9.83	10.47
Aug	0.71	5.10	5.10	5.31	5.05	5.10	5.18	5.01	4.77	5.25
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		43.96	43.96	45.81	45.86	43.82	41.88	44.05	41.62	44.69

Table A-24 - In-Season Infiltrated Rainfall with Rice (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	3.83	4.00	4.18	0.54	0.73	2.60	1.90	1.41	0.99

Table A-25 - Off-Season Infiltrated Rainfall with Rice (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	3.11	2.86	5.79	3.59	3.11	2.37	3.13	2.65	2.00

Table A-26 - Seed Alfalfa Crop Coefficients and Monthly/Annual ETc's (in)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.5	0.58	0.58	0.43	0.49	0.48	0.62	0.66	0.61	0.75
Feb	0.9	1.85	1.85	1.62	1.94	2.13	1.83	1.54	2.39	1.53
Mar	1.1	4.31	4.31	3.30	5.06	3.88	3.85	4.16	5.72	4.21
Apr	1.1	6.29	6.29	5.32	6.35	7.07	6.15	7.32	5.48	6.33
May	1.1	8.74	8.74	9.68	9.86	8.32	8.25	8.48	7.98	8.65
Jun	1.01	8.52	8.52	9.67	8.64	8.66	8.12	8.37	7.54	8.67
Jul	0.69	5.87	5.87	6.38	5.91	5.65	5.45	5.69	5.80	6.18
Aug	0.28	2.01	2.01	2.09	1.99	2.01	2.04	1.98	1.88	2.07
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.07	0.13	0.13	0.09	0.12	0.13	0.18	0.11	0.11	0.14
Dec	0.13	0.14	0.14	0.12	0.23	0.10	0.09	0.18	0.12	0.14
Annual		38.44	38.44	38.70	40.59	38.43	36.58	38.49	37.62	38.65

Table A-27 - In-Season Infiltrated Rainfall with Seed Alfalfa (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.41	0.63	2.65	0.09	0.54	0.10	1.00	1.03	0.26
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	5.94	5.22	8.40	1.84	1.35	5.13	4.56	2.86	2.26

Table A-28 - Off-Season Infiltrated Rainfall with Seed Alfalfa (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	1.83	2.32	2.15	2.72	2.84	0.28	1.31	1.76	1.20

Table A-29 - Sorghum Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.05	0.29	0.29	0.24	0.29	0.32	0.28	0.33	0.25	0.29
May	0.16	1.27	1.27	1.41	1.43	1.21	1.20	1.23	1.16	1.26
Jun	0.54	4.56	4.56	5.17	4.62	4.63	4.34	4.48	4.03	4.63
Jul	1.02	8.67	8.67	9.42	8.74	8.35	8.06	8.42	8.57	9.13
Aug	0.92	6.61	6.61	6.88	6.54	6.61	6.72	6.50	6.18	6.81
Sep	0.6	3.28	3.28	3.44	3.77	3.24	3.04	3.24	3.19	3.07
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		24.67	24.67	26.56	25.39	24.37	23.64	24.19	23.38	25.19

Table A-30 - In-Season Infiltrated Rainfall with Sorghum (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	0.00	0.81	1.10	0.07	0.05	0.43	0.11	0.26	1.27

Table A-31 - Off-Season Infiltrated Rainfall with Sorghum (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.79	1.09	0.34	0.01	0.06	0.20	0.00	0.68	0.05
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	6.49	5.57	8.74	3.80	3.42	4.14	4.64	3.40	1.59

Table A-32 - Almond/Stonefruit (w/ cover) Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.47	1.84	1.84	1.41	2.16	1.66	1.65	1.78	2.44	1.80
Apr	0.78	4.46	4.46	3.78	4.50	5.02	4.36	5.19	3.88	4.49
May	0.89	7.07	7.07	7.83	7.97	6.73	6.68	6.86	6.45	7.00
Jun	0.97	8.19	8.19	9.28	8.29	8.31	7.80	8.04	7.25	8.32
Jul	0.98	8.33	8.33	9.06	8.40	8.03	7.74	8.09	8.23	8.77
Aug	0.98	7.04	7.04	7.33	6.97	7.05	7.15	6.92	6.59	7.25
Sep	0.96	5.25	5.25	5.50	6.03	5.18	4.87	5.18	5.10	4.92
Oct	0.61	2.27	2.27	2.10	2.34	2.37	2.45	2.23	2.01	2.40
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		44.45	44.45	46.29	46.66	44.34	42.69	44.29	41.96	44.94

Table A-33 - In-Season Infiltrated Rainfall with Almond/Stonefruit (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.33	0.54	0.53	0.50	0.44	0.00	0.75	0.00	0.58
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	4.17	5.24	5.40	1.04	1.17	2.92	2.65	1.41	2.76

Table A-34 - Off-Season Infiltrated Rainfall with Almond/Stonefruit (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	2.96	2.31	5.25	3.37	2.92	2.23	2.80	2.65	0.93

Table A-35 - Sugarbeet (North of Nees Ave.) Crop Coeff. and Monthly/Annual Etc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.09	1.25	1.25	0.93	1.07	1.05	1.35	1.44	1.32	1.62
Feb	1.04	2.14	2.14	1.87	2.25	2.46	2.11	1.78	2.76	1.77
Mar	0.65	2.55	2.55	1.95	2.99	2.29	2.28	2.46	3.38	2.49
Apr	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.42	3.54	3.54	4.02	3.59	3.60	3.38	3.48	3.14	3.60
Jul	0.93	7.91	7.91	8.59	7.97	7.62	7.35	7.67	7.81	8.32
Aug	1.1	7.90	7.90	8.23	7.82	7.91	8.03	7.77	7.39	8.14
Sep	1.1	6.02	6.02	6.30	6.91	5.94	5.58	5.94	5.84	5.63
Oct	1.1	4.10	4.10	3.80	4.21	4.27	4.42	4.03	3.63	4.33
Nov	1.1	1.99	1.99	1.49	1.93	1.99	2.79	1.78	1.75	2.18
Dec	1.1	1.19	1.19	1.05	1.91	0.85	0.80	1.53	1.03	1.16
Annual		38.59	38.59	38.22	40.65	37.98	38.09	37.87	38.05	39.25

Table A-36 - In-Season Infiltrated Rainfall with Sugarbeets (North) (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.41	0.63	2.65	0.09	0.54	0.10	1.00	1.03	0.26
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.33	0.54	0.53	0.50	0.44	0.00	0.75	0.00	0.58
Nov	1.87	1.67	1.00	0.92	2.33	0.00	0.53	0.60	0.28
Dec	0.24	0.90	1.35	2.22	0.87	0.32	1.08	1.77	0.00
Annual	7.24	7.45	10.81	5.45	4.87	5.20	6.81	3.99	4.10

Table A-37 - Off-Season Infiltrated Rainfall with Sugarbeets (North) (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.79	1.09	0.34	0.01	0.06	0.20	0.00	0.68	0.05
May	0.00	0.00	0.18	0.00	0.00	0.05	0.05	0.12	0.04
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	0.79	1.09	0.52	0.01	0.06	0.25	0.05	0.79	0.09

Table A-38 - Sugarbeet (South of Nees) Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.08	0.09	0.09	0.07	0.08	0.08	0.10	0.11	0.10	0.12
Feb	0.24	0.49	0.49	0.43	0.52	0.57	0.49	0.41	0.64	0.41
Mar	0.33	1.29	1.29	0.99	1.52	1.16	1.16	1.25	1.72	1.26
Apr	0.8	4.57	4.57	3.87	4.62	5.14	4.47	5.32	3.98	4.60
May	1.12	8.90	8.90	9.86	10.04	8.47	8.40	8.64	8.12	8.80
Jun	1.12	9.45	9.45	10.72	9.58	9.60	9.00	9.28	8.37	9.61
Jul	1.06	9.01	9.01	9.79	9.08	8.68	8.37	8.75	8.90	9.49
Aug	0.65	4.67	4.67	4.86	4.62	4.67	4.75	4.59	4.37	4.81
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		38.48	38.48	40.59	40.05	38.38	36.74	38.34	36.19	39.10

Table A-39 - In-Season Infiltrated Rainfall with Sugarbeet (South) (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	4.53	4.59	5.75	1.75	0.81	5.03	3.56	1.83	2.00

Table A-40 - Off-Season Infiltrated Rainfall with Sugarbeet (South) (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	2.80	2.60	4.71	2.76	3.08	0.33	1.99	2.47	1.31

Table A-41 - Tomato Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.08	0.31	0.31	0.24	0.37	0.28	0.28	0.30	0.42	0.31
Apr	0.24	1.37	1.37	1.16	1.38	1.54	1.34	1.60	1.20	1.38
May	0.42	3.34	3.34	3.70	3.76	3.18	3.15	3.24	3.05	3.30
Jun	0.89	7.51	7.51	8.52	7.61	7.63	7.16	7.38	6.65	7.64
Jul	1.08	9.18	9.18	9.98	9.26	8.85	8.53	8.91	9.07	9.67
Aug	0.85	6.10	6.10	6.36	6.04	6.11	6.21	6.00	5.71	6.29
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		27.82	27.82	29.95	28.42	27.58	26.66	27.43	26.09	28.58

Table A-42 - In-Season Infiltrated Rainfall with Tomatoes (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	1.16	1.69	1.16	0.10	0.17	0.57	0.11	1.25	0.20

Table A-43 - Off-Season Infiltrated Rainfall with Tomatoes (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	2.59	1.94	2.92	0.20	0.25	1.71	1.51	0.07	0.35
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	5.70	4.80	8.72	3.78	3.36	4.08	4.64	2.72	2.35

Table A-44 - Vegetable Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.44	0.91	0.91	0.79	0.95	1.04	0.89	0.75	1.17	0.75
Mar	0.71	2.78	2.78	2.13	3.27	2.51	2.49	2.68	3.69	2.72
Apr	1.12	6.40	6.40	5.42	6.46	7.20	6.26	7.45	5.58	6.44
May	0.79	6.28	6.28	6.95	7.08	5.97	5.93	6.09	5.73	6.21
Jun	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		16.37	16.37	15.29	17.76	16.72	15.56	16.98	16.16	16.12

Table A-45 - In-Season Infiltrated Rainfall with Vegetables (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	4.53	4.49	5.75	1.68	0.77	5.03	3.56	1.83	2.00

Table A-46 - Off-Season Infiltrated Rainfall with Vegetables (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.05	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	2.80	2.64	4.71	2.79	3.10	0.33	1.99	2.47	1.31

Table A-47 - Walnut Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.52	2.04	2.04	1.56	2.39	1.84	1.82	1.97	2.70	1.99
Apr	0.9	5.14	5.14	4.36	5.19	5.79	5.03	5.99	4.48	5.18
May	1.07	8.50	8.50	9.42	9.59	8.09	8.03	8.25	7.76	8.41
Jun	1.17	9.87	9.87	11.20	10.00	10.03	9.41	9.70	8.74	10.04
Jul	1.17	9.95	9.95	10.81	10.03	9.58	9.24	9.65	9.83	10.47
Aug	1.17	8.40	8.40	8.75	8.32	8.41	8.54	8.26	7.86	8.66
Sep	1.16	6.35	6.35	6.65	7.28	6.26	5.88	6.26	6.16	5.94
Oct	1.08	4.02	4.02	3.73	4.14	4.19	4.34	3.95	3.56	4.26
Nov	0.34	0.61	0.61	0.46	0.60	0.62	0.86	0.55	0.54	0.67
Dec	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual		54.89	54.89	56.92	57.54	54.80	53.15	54.58	51.64	55.61

Table A-48 - In-Season Infiltrated Rainfall with Walnuts (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.11	0.00	0.07	0.05	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.70	0.69	0.00	0.00	0.32	0.00	0.00	1.19
Oct	0.33	0.54	0.53	0.50	0.44	0.00	0.75	0.00	0.58
Nov	1.87	1.67	1.00	0.92	2.33	0.00	0.53	0.60	0.28
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	6.04	6.91	6.40	1.95	3.50	2.92	3.18	2.01	3.04

Table A-49 - Off-Season Infiltrated Rainfall with Walnuts (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.97	0.28	2.56	0.04	0.24	0.04	0.68	0.71	0.12
Feb	0.31	0.26	1.08	0.83	0.04	2.04	1.14	0.18	0.69
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	1.39	1.16	4.56	2.74	0.66	2.23	2.56	2.38	0.81

Table A-50 - Wheat Crop Coefficients and Monthly/Annual ETc's (inches)

MONTH	Kc	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.54	0.62	0.62	0.46	0.53	0.52	0.67	0.71	0.65	0.80
Feb	0.96	1.98	1.98	1.73	2.07	2.28	1.95	1.64	2.54	1.63
Mar	1.17	4.59	4.59	3.51	5.38	4.13	4.10	4.42	6.08	4.48
Apr	1.08	6.17	6.17	5.23	6.23	6.94	6.04	7.18	5.38	6.21
May	0.52	4.13	4.13	4.58	4.66	3.93	3.90	4.01	3.77	4.09
Jun	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.15	0.16	0.16	0.14	0.26	0.12	0.11	0.21	0.14	0.16
Annual		17.65	17.65	15.64	19.14	17.91	16.76	18.18	18.57	17.37

Table A-51 - In-Season Infiltrated Rainfall with Wheat (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	1.41	0.63	2.65	0.09	0.54	0.10	1.00	1.03	0.26
Feb	0.70	0.59	1.58	1.21	0.08	2.43	1.66	0.41	1.01
Mar	2.68	2.31	3.02	0.44	0.56	2.03	1.79	0.16	0.79
Apr	1.16	1.58	0.76	0.03	0.13	0.46	0.00	0.99	0.12
May	0.00	0.00	0.41	0.00	0.00	0.11	0.11	0.26	0.08
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual	5.94	5.12	8.40	1.77	1.31	5.13	4.56	2.86	2.26

Table A-52 - Off-Season Infiltrated Rainfall with Wheat (inches)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.05	0.00	0.03	0.02	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.31	0.31	0.00	0.00	0.14	0.00	0.00	0.82
Oct	0.15	0.24	0.24	0.22	0.20	0.00	0.33	0.00	0.26
Nov	1.58	1.15	0.68	0.63	2.25	0.00	0.24	0.27	0.12
Dec	0.11	0.62	0.92	1.87	0.39	0.14	0.74	1.49	0.00
Annual	1.83	2.36	2.15	2.75	2.86	0.28	1.31	1.76	1.20

TABLE A-53 - Broadview Water District - 1981 Data

1981 DATA 3.21 dS/m = DELIVERED WATER QUALITY
4 dS/m = THRESHHOLD ECe

55.63 inches = ANNUAL ETo (long-term ave.)
10.17 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11 WATER REQ W/ REC UNADJUST. ETc In	12 WATER REQ W/ REC ADJUST. ETc In
FALLOW	0	3.42	1.000	3.42	5.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC	290	16.37	0.876	14.34	7.33	0.00	2.14	11.18	9.15	0.00	11.18	9.15
COTTON	5669	28.11	0.876	24.63	6.49	1.41	5.11	25.33	21.84	0.00	25.33	21.84
ALFALFA	0	55.67	0.876	48.77	8.39	2.78	11.18	55.67	48.77	0.00	55.67	48.77
WHEAT	1046	17.65	0.876	15.46	7.77	0.44	2.34	11.77	9.58	0.00	11.77	9.58
MELONS	0	14.05	0.876	12.31	6.85	0.35	2.23	9.07	7.33	0.00	9.07	7.33
TOMATOES	220	27.82	0.876	24.37	6.85	1.39	4.96	24.53	21.08	0.00	24.53	21.08
SUGARBEET	0	38.48	0.876	33.71	7.33	1.92	7.36	36.59	31.82	0.00	36.59	31.82
BARLEY	547	15.03	0.876	13.16	7.77	0.38	1.71	8.59	6.73	0.00	8.59	6.73
BEANS	623	21.34	0.876	18.70	6.49	0.53	3.91	18.23	15.58	0.00	18.23	15.58
SD ALFALFA	630	38.44	0.876	33.67	7.77	1.92	7.25	35.99	31.22	0.00	35.99	31.22
RICE	0	43.96	0.876	38.51	6.94	2.20	8.75	43.57	38.12	0.00	43.57	38.12
CORN	0	28.79	0.876	25.22	6.49	0.72	5.27	26.85	23.28	0.00	26.85	23.28
VEGETABLE	0	16.37	0.876	14.34	7.33	0.00	2.14	11.18	9.15	0.00	11.18	9.15
PASTURE	0	51.30	0.876	44.94	8.39	2.56	10.14	50.48	44.12	0.00	50.48	44.12
ALMOND-STONE	0	44.45	0.876	38.94	7.13	2.22	8.82	43.93	38.42	0.00	43.93	38.42
WALNUT	0	54.89	0.876	48.09	7.43	2.74	11.22	55.94	49.14	0.00	55.94	49.14
MILO	0	24.67	0.876	21.61	6.49	0.62	4.41	21.98	18.92	0.00	21.98	18.92

TABLE A-54 - Broadview Water District - 1982 Data

1982 DATA 2.89 dS/m = DELIVERED WATER QUALITY 55.63 inches = ANNUAL ETo (long-term ave.)
2.5 dS/m = THRESHHOLD ECe 10.38 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11 WATER REQ W/ REC UNADJUST. ETc	12 WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	334	3.42	1.000	3.42	4.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC	300	16.37	0.876	14.34	7.13	0.00	3.97	13.22	11.19	0.00	13.22	11.19
COTTON	5283	28.11	0.876	24.63	6.38	1.41	9.34	29.67	26.18	0.00	29.67	26.18
ALFALFA	0	55.67	0.876	48.77	9.04	2.78	20.05	63.90	57.00	0.00	63.90	57.00
WHEAT	1149	17.65	0.876	15.46	7.48	0.44	4.38	14.11	11.92	0.00	14.11	11.92
MELONS	455	14.05	0.876	12.31	6.49	0.35	4.00	11.21	9.47	0.00	11.21	9.47
TOMATOES	0	27.82	0.876	24.37	6.49	1.39	9.17	29.11	25.66	0.00	29.11	25.66
SUGARBEET	300	38.48	0.876	33.71	7.19	1.92	13.46	42.83	38.06	0.00	42.83	38.06
BARLEY	741	15.03	0.876	13.16	7.48	0.38	3.25	10.42	8.55	0.00	10.42	8.55
BEANS	40	21.34	0.876	18.70	5.99	0.53	7.07	21.88	19.24	0.00	21.88	19.24
SD ALFALFA	560	38.44	0.876	33.67	7.54	1.92	13.29	42.26	37.50	0.00	42.26	37.50
RICE	0	43.96	0.876	38.51	6.86	2.20	15.96	50.86	45.41	0.00	50.86	45.41
CORN	0	28.79	0.876	25.22	6.38	0.72	9.64	31.32	27.75	0.00	31.32	27.75
VEGETABLE	0	16.37	0.876	14.34	7.13	0.00	3.97	13.22	11.19	0.00	13.22	11.19
PASTURE	0	51.30	0.876	44.94	9.04	2.56	18.17	57.87	51.51	0.00	57.87	51.51
ALMOND-STONE	0	44.45	0.876	38.94	7.55	2.22	15.87	50.55	45.04	0.00	50.55	45.04
WALNUT	0	54.89	0.876	48.09	8.07	2.74	20.13	64.21	57.40	0.00	64.21	57.40
MILO	0	24.67	0.876	21.61	6.38	0.62	7.87	25.54	22.48	0.00	25.54	22.48

TABLE A-55 - Broadview Water District - 1983 Data

1983 DATA

0.89 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
3924 AF = COLLECTED TILE DRAINAGE

57.06 inches = ANNUAL ETo
15.23 inches = ANNUAL PPT
3.20 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	3790	3.42	1.000	3.42	6.89	0.00	-0.31	0.00	0.00	3.20	0.00	0.00
MISC	0	15.29	0.876	13.40	8.31	0.00	0.63	7.61	5.72	3.20	8.67	6.77
COTTON	2035	30.25	0.876	26.50	9.84	1.51	1.82	20.72	16.97	3.20	23.92	20.17
ALFALFA	160	55.99	0.876	49.05	11.97	2.80	3.65	44.88	37.94	3.20	48.08	41.14
WHEAT	835	15.64	0.876	13.70	10.55	0.39	0.42	5.12	3.18	3.20	8.33	6.39
MELONS	450	15.36	0.876	13.45	5.64	0.38	0.88	10.21	8.31	3.20	10.21	8.31
TOMATOES	300	29.95	0.876	26.24	9.88	1.50	1.79	20.37	16.66	3.20	23.57	19.86
SUGARBEET	300	40.59	0.876	35.56	10.46	2.03	2.56	30.66	25.62	3.20	33.86	28.83
BARLEY	250	13.30	0.876	11.65	10.55	0.33	0.23	2.64	0.99	3.20	5.85	4.20
BEANS	745	23.49	0.876	20.58	6.72	0.59	1.52	17.70	14.79	3.20	18.17	15.26
SD ALFALFA	435	38.70	0.876	33.90	10.55	1.94	2.34	28.55	23.75	3.20	31.76	26.96
RICE	0	45.81	0.876	40.13	9.97	2.29	2.98	36.52	30.84	3.20	39.73	34.05
CORN	0	31.17	0.876	27.30	9.84	0.78	1.90	22.44	18.58	3.20	25.65	21.78
VEGETABLE	0	15.29	0.876	13.40	8.31	0.00	0.63	7.61	5.72	3.20	8.67	6.77
PASTURE	0	51.35	0.876	44.99	11.97	2.57	3.27	40.09	33.72	3.20	43.29	36.92
ALMOND-STONE	0	46.29	0.876	40.55	10.65	2.31	2.96	36.29	30.55	3.20	39.49	33.75
WALNUT	0	56.92	0.876	49.86	10.96	2.85	3.82	46.93	39.87	3.20	50.13	43.08
MILO	0	26.56	0.876	23.27	8.71	0.66	1.62	18.80	15.51	3.20	20.88	17.58

TABLE A-56 - Broadview Water District - 1984 Data

1984 DATA

0.74 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
3924 AF = COLLECTED TILE DRAINAGE

60.03 inches = ANNUAL ETo
6.35 inches = ANNUAL PPT
2.62 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	95	3.62	1.000	3.62	3.81	0.00	-0.01	0.00	0.00	2.62	2.40	2.40
MISC	140	17.76	0.876	15.56	4.47	0.00	0.89	14.18	11.98	2.62	16.81	14.60
COTTON	4905	28.95	0.876	25.36	3.87	1.45	1.68	25.32	21.73	2.62	27.95	24.36
ALFALFA	160	58.68	0.876	51.41	5.48	2.93	3.57	53.85	46.57	2.62	56.47	49.19
WHEAT	900	19.14	0.876	16.76	4.52	0.48	0.98	15.12	12.75	2.62	17.75	15.37
MELONS	300	14.68	0.876	12.86	3.88	0.37	0.74	11.16	9.34	2.62	13.79	11.97
TOMATOES	150	28.42	0.876	24.90	3.88	1.42	1.65	24.77	21.24	2.62	27.39	23.87
SUGARBEET	1355	40.05	0.876	35.08	4.51	2.00	2.39	35.93	30.96	2.62	38.55	33.58
BARLEY	190	16.28	0.876	14.26	4.52	0.41	0.79	12.15	10.13	2.62	14.77	12.75
BEANS	300	22.25	0.876	19.49	3.87	0.56	1.23	19.06	16.30	2.62	21.69	18.93
SD ALFALFA	560	40.59	0.876	35.55	4.56	2.03	2.42	36.42	31.39	2.62	39.04	34.01
RICE	0	45.86	0.876	40.17	4.13	2.29	2.80	42.24	36.56	2.62	44.87	39.18
CORN	0	29.59	0.876	25.92	3.87	0.74	1.73	26.71	23.04	2.62	29.33	25.66
VEGETABLE	0	17.76	0.876	15.56	4.47	0.00	0.89	14.18	11.98	2.62	16.81	14.60
PASTURE	0	54.27	0.876	47.54	5.48	2.71	3.28	49.36	42.63	2.62	51.98	45.25
ALMOND-STONE	0	46.66	0.876	40.88	4.40	2.33	2.84	42.76	36.98	2.62	45.39	39.60
WALNUT	0	57.54	0.876	50.40	4.69	2.88	3.55	53.52	46.38	2.62	56.14	49.01
MILO	0	25.39	0.876	22.24	3.87	0.63	1.45	22.33	19.18	2.62	24.96	21.81

TABLE A-57 - Broadview Water District - 1985 Data

1985 DATA

0.64 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
3924 AF = COLLECTED TILE DRAINAGE

56.66 inches = ANNUAL ETo
6.07 inches = ANNUAL PPT
2.97 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	345	3.40	1.000	3.40	3.44	0.00	-0.00	0.00	0.00	2.97	2.93	2.93
MISC	150	16.72	0.876	14.65	3.86	0.00	0.73	13.59	11.52	2.97	16.56	14.49
COTTON	4037	27.83	0.876	24.38	3.46	1.39	1.39	24.37	20.91	2.97	27.34	23.89
ALFALFA	150	55.59	0.876	48.70	5.00	2.78	2.89	50.70	43.81	2.97	53.67	46.78
WHEAT	983	17.91	0.876	15.69	4.16	0.45	0.78	14.09	11.87	2.97	17.06	14.84
MELONS	790	14.01	0.876	12.27	3.53	0.35	0.60	10.72	8.99	2.97	13.70	11.96
TOMATOES	750	27.58	0.876	24.16	3.53	1.38	1.37	24.04	20.62	2.97	27.01	23.59
SUGARBEET	750	38.38	0.876	33.62	3.89	1.92	1.97	34.53	29.78	2.97	37.51	32.75
BARLEY	425	15.24	0.876	13.35	4.16	0.38	0.63	11.33	9.44	2.97	14.30	12.41
BEANS	0	21.12	0.876	18.50	3.46	0.53	1.01	18.14	15.52	2.97	21.11	18.49
SD ALFALFA	630	38.43	0.876	33.67	4.19	1.92	1.95	34.27	29.51	2.97	37.25	32.48
RICE	0	43.82	0.876	38.39	3.84	2.19	2.28	40.06	34.63	2.97	43.04	37.60
CORN	0	28.48	0.876	24.95	3.46	0.71	1.43	25.73	22.20	2.97	28.70	25.17
VEGETABLE	0	16.72	0.876	14.65	3.86	0.00	0.73	13.59	11.52	2.97	16.56	14.49
PASTURE	0	50.99	0.876	44.67	5.00	2.55	2.62	46.07	39.75	2.97	49.04	42.72
ALMOND-STONE	0	44.34	0.876	38.84	4.09	2.22	2.30	40.33	34.83	2.97	43.30	37.80
WALNUT	0	54.80	0.876	48.01	4.17	2.74	2.89	50.78	43.99	2.97	53.76	46.96
MILO	0	24.37	0.876	21.35	3.46	0.61	1.19	21.49	18.47	2.97	24.46	21.44

TABLE A-58 - Broadview Water District - 1986 Data

1986 DATA

0.67 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
4626 AF = COLLECTED TILE DRAINAGE

55.46 inches = ANNUAL ETo
6.81 inches = ANNUAL PPT
3.75 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	854	3.33	1.000	3.33	4.27	0.00	-0.06	0.00	0.00	3.75	2.69	2.69
MISC	140	15.56	0.876	13.63	5.36	0.00	0.61	10.82	8.89	3.75	14.57	12.64
COTTON	4231	26.99	0.876	23.64	4.57	1.35	1.35	22.42	19.07	3.75	26.17	22.82
ALFALFA	147	54.20	0.876	47.48	5.77	2.71	2.91	48.63	41.91	3.75	52.38	45.66
WHEAT	968	16.76	0.876	14.68	5.41	0.42	0.68	11.61	9.53	3.75	15.36	13.28
MELONS	670	13.32	0.876	11.66	4.65	0.33	0.55	8.89	7.23	3.75	12.64	10.99
TOMATOES	750	26.66	0.876	23.36	4.65	1.33	1.32	22.01	18.70	3.75	25.76	22.45
SUGARBEET	425	36.74	0.876	32.18	5.36	1.84	1.88	31.42	26.87	3.75	35.18	30.62
BARLEY	113	14.31	0.876	12.54	5.41	0.36	0.53	9.08	7.30	3.75	12.83	11.05
BEANS	20	20.17	0.876	17.67	4.39	0.50	0.95	16.22	13.72	3.75	19.98	17.47
SD ALFALFA	705	36.58	0.876	32.05	5.41	1.83	1.87	31.21	26.67	3.75	34.96	30.43
RICE	0	41.88	0.876	36.69	4.97	2.09	2.22	37.03	31.84	3.75	40.78	35.59
CORN	0	27.56	0.876	24.15	4.57	0.69	1.38	23.68	20.27	3.75	27.44	24.02
VEGETABLE	0	15.56	0.876	13.63	5.36	0.00	0.61	10.82	8.89	3.75	14.57	12.64
PASTURE	0	49.91	0.876	43.72	5.77	2.50	2.65	44.30	38.11	3.75	48.05	41.86
ALMOND-STONE	0	42.69	0.876	37.40	5.15	2.13	2.25	37.66	32.37	3.75	41.41	36.12
WALNUT	0	53.15	0.876	46.56	5.15	2.66	2.88	48.23	41.63	3.75	51.98	45.39
MILO	0	23.64	0.876	20.71	4.57	0.59	1.14	19.62	16.69	3.75	23.37	20.44

TABLE A-59 - Broadview Water District - 1987 Data

1987 DATA	0.56 dS/m = DELIVERED WATER QUALITY	56.84 inches = ANNUAL ETo
	2.5 dS/m = THRESHHOLD ECe	7.96 inches = ANNUAL PPT
	3704 AF = COLLECTED TILE DRAINAGE	3.03 inches = REC LEACHING

	1	2	3	4	5	6	7	8	9	10	11	12
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ REC UNADJUST. ETc	WATER REQ W/ REC ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	1128	3.41	1.000	3.41	4.62	0.00	-0.06	0.00	0.00	3.03	1.70	1.70
MISC	75	16.98	0.876	14.87	5.55	0.00	0.56	11.99	9.88	3.03	15.02	12.91
COTTON	3721	27.60	0.876	24.18	4.74	1.38	1.12	22.60	19.18	3.03	25.63	22.21
ALFALFA	0	55.29	0.876	48.43	6.91	2.76	2.38	47.99	41.13	3.03	51.02	44.17
WHEAT	1160	18.18	0.876	15.92	5.86	0.45	0.61	12.46	10.21	3.03	15.50	13.24
MELONS	1080	13.91	0.876	12.19	4.21	0.35	0.50	9.86	8.13	3.03	12.36	10.63
TOMATOES	450	27.43	0.876	24.02	4.74	1.37	1.12	22.43	19.03	3.03	25.46	22.06
SUGARBEET	300	38.34	0.876	33.58	5.55	1.92	1.61	32.48	27.73	3.03	35.51	30.76
BARLEY	54	15.46	0.876	13.54	5.86	0.39	0.47	9.68	7.76	3.03	12.71	10.79
BEANS	0	20.99	0.876	18.39	4.74	0.52	0.80	16.52	13.92	3.03	19.55	16.95
SD ALFALFA	1030	38.49	0.876	33.72	5.86	1.92	1.61	32.31	27.53	3.03	35.34	30.57
RICE	0	44.05	0.876	38.58	5.03	2.20	1.92	38.73	33.27	3.03	41.77	36.31
CORN	0	28.27	0.876	24.76	4.74	0.71	1.16	23.97	20.47	3.03	27.01	23.50
VEGETABLE	0	16.98	0.876	14.87	5.55	0.00	0.56	11.99	9.88	3.03	15.02	12.91
PASTURE	0	51.16	0.876	44.81	6.91	2.56	2.18	43.86	37.52	3.03	46.89	40.55
ALMOND-STONE	0	44.29	0.876	38.80	5.44	2.21	1.91	38.54	33.05	3.03	41.57	36.08
WALNUT	0	54.58	0.876	47.81	5.74	2.73	2.40	48.52	41.75	3.03	51.55	44.78
MILO	0	24.19	0.876	21.19	4.74	0.60	0.96	19.80	16.80	3.03	22.83	19.83

TABLE A-60 - Broadview Water District - 1988 Data

1988 DATA

0.87 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
3628 AF = COLLECTED TILE DRAINAGE

55.02 inches = ANNUAL ETo
6.24 inches = ANNUAL PPT
2.35 inches = REC LEACHING

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11 WATER REQ W/ REC UNADJUST. ETc In	12 WATER REQ W/ REC ADJUST. ETc In
FALLOW	531	3.30	1.000	3.30	3.50	0.00	-0.02	0.00	0.00	2.35	2.12	2.12
MISC	0	16.16	0.876	14.16	4.29	0.00	0.96	12.83	10.83	2.35	15.18	13.17
COTTON	4348	26.46	0.876	23.18	3.66	1.32	1.84	23.32	20.04	2.35	25.67	22.39
ALFALFA	0	53.77	0.876	47.10	5.24	2.69	3.92	49.77	43.10	2.35	52.12	45.45
WHEAT	689	18.57	0.876	16.27	4.62	0.46	1.13	14.62	12.31	2.35	16.97	14.66
MELONS	1535	12.83	0.876	11.24	3.97	0.32	0.72	9.26	7.67	2.35	11.61	10.01
TOMATOES	680	26.09	0.876	22.85	3.97	1.30	1.79	22.60	19.36	2.35	24.95	21.71
SUGARBEET	454	36.19	0.876	31.70	4.29	1.81	2.58	32.67	28.18	2.35	35.02	30.53
BARLEY	150	15.79	0.876	13.83	4.62	0.39	0.90	11.68	9.72	2.35	14.03	12.07
BEANS	175	19.65	0.876	17.21	3.66	0.49	1.29	16.79	14.35	2.35	19.14	16.70
SD ALFALFA	705	37.62	0.876	32.95	4.62	1.88	2.67	33.79	29.12	2.35	36.14	31.47
RICE	0	41.62	0.876	36.46	4.06	2.08	3.04	38.51	33.35	2.35	40.86	35.70
CORN	0	27.03	0.876	23.68	3.66	0.68	1.89	24.58	21.23	2.35	26.93	23.58
VEGETABLE	0	16.16	0.876	14.16	4.29	0.00	0.96	12.83	10.83	2.35	15.18	13.17
PASTURE	0	49.52	0.876	43.38	5.24	2.48	3.58	45.39	39.25	2.35	47.74	41.60
ALMOND-STONE	0	41.96	0.876	36.75	4.06	2.10	3.06	38.86	33.66	2.35	41.21	36.00
WALNUT	0	51.64	0.876	45.23	4.40	2.58	3.82	48.48	42.07	2.35	50.83	44.42
MILO	0	23.38	0.876	20.48	3.66	0.58	1.59	20.73	17.83	2.35	23.08	20.18

TABLE A-61 - Broadview Water District - 1989 Data

1989 DATA

0.75 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe
3736 AF = COLLECTED TILE DRAINAGE

57.65 inches = ANNUAL ETo
2.54 inches = ANNUAL PPT
2.57 inches = REC LEACHING

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11 WATER REQ W/ REC UNADJUST. ETc In	12 WATER REQ W/ REC ADJUST. ETc In
FALLOW	322	3.46	1.000	3.46	2.44	0.00	0.07	1.09	1.09	2.57	3.65	3.65
MISC	178	16.12	0.876	14.12	3.31	0.00	0.87	13.68	11.68	2.57	16.25	14.25
COTTON	4649	28.69	0.876	25.13	2.86	1.43	1.76	26.16	22.60	2.57	28.72	25.16
ALFALFA	72	56.17	0.876	49.20	4.30	2.81	3.54	52.59	45.63	2.57	55.16	48.20
WHEAT	708	17.37	0.876	15.22	3.45	0.43	0.95	14.43	12.28	2.57	17.00	14.85
MELONS	1279	14.24	0.876	12.47	2.55	0.36	0.80	12.12	10.36	2.57	14.69	12.92
TOMATOES	850	28.58	0.876	25.04	2.55	1.43	1.77	26.37	22.83	2.57	28.94	25.40
SUGARBEET	150	39.10	0.876	34.25	3.31	1.96	2.44	36.28	31.43	2.57	38.84	34.00
BARLEY	41	14.80	0.876	12.97	3.45	0.37	0.77	11.75	9.92	2.57	14.32	12.48
BEANS	75	21.72	0.876	19.03	2.49	0.54	1.31	20.00	17.31	2.57	22.57	19.87
SD ALFALFA	694	38.65	0.876	33.86	3.45	1.93	2.40	35.66	30.87	2.57	38.23	33.43
RICE	0	44.69	0.876	39.15	2.99	2.23	2.84	42.31	36.76	2.57	44.87	39.33
CORN	0	29.44	0.876	25.79	2.86	0.74	1.81	27.66	24.01	2.57	30.23	26.57
VEGETABLE	0	16.12	0.876	14.12	3.31	0.00	0.87	13.68	11.68	2.57	16.25	14.25
PASTURE	0	51.89	0.876	45.45	4.30	2.59	3.24	48.23	41.80	2.57	50.80	44.36
ALMOND-STONE	0	44.94	0.876	39.37	3.69	2.25	2.81	41.82	36.25	2.57	44.39	38.82
WALNUT	0	55.61	0.876	48.72	3.84	2.78	3.53	52.52	45.62	2.57	55.09	48.19
MILO	0	25.19	0.876	22.06	2.86	0.63	1.52	23.22	20.10	2.57	25.78	22.66

TABLE A-62 - Firebaugh Canal Water District - 1982 Data

1982 DATA 0.54 dS/m = DELIVERED WATER QUALITY 55.63 inches = ANNUAL ETo (long-term ave.)
2.5 dS/m = THRESHHOLD ECe 10.38 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.42	1.000	3.42	5.81	0.00	-0.12	0.00	0.00	0.00	0.00	0.00
MISC	0	16.37	0.876	14.34	7.13	0.00	0.44	9.68	7.65	0.00	9.68	7.65
COTTON	9536	28.11	0.876	24.63	6.38	1.41	1.03	21.35	17.86	0.00	22.76	19.27
ALFALFA	522	55.67	0.876	48.77	9.04	2.78	2.21	46.05	39.15	0.00	48.84	41.93
WHEAT	3921	17.65	0.876	15.46	7.48	0.44	0.48	10.21	8.03	0.00	10.66	8.47
MELONS	0	14.05	0.876	12.31	5.18	0.35	0.44	8.96	7.22	0.00	9.31	7.57
TOMATOES	0	27.82	0.876	24.37	6.49	1.39	1.01	20.94	17.49	0.00	22.33	18.89
SUGARBEET	1951	38.48	0.876	33.71	7.19	1.92	1.48	30.85	26.08	0.00	32.77	28.00
BARLEY	0	15.03	0.876	13.16	7.48	0.38	0.36	7.53	5.66	0.00	7.90	6.04
BEANS	0	21.34	0.876	18.70	5.69	0.53	0.78	15.90	13.25	0.00	16.43	13.79
SD ALFALFA	0	38.44	0.876	33.67	7.54	1.92	1.46	30.44	25.67	0.00	32.36	27.59
RICE	1946	43.96	0.876	38.51	6.86	2.20	1.75	36.66	31.21	0.00	38.86	33.40
CORN	125	28.79	0.876	25.22	6.38	0.72	1.06	22.75	19.18	0.00	23.47	19.90
VEGETABLE	2208	16.37	0.876	14.34	7.13	0.00	0.44	9.68	7.65	0.00	9.68	7.65
PASTURE	0	51.30	0.876	44.94	9.04	2.56	2.00	41.69	35.33	0.00	44.26	37.90
ALMOND-STONE	0	44.45	0.876	38.94	7.55	2.22	1.75	36.43	30.91	0.00	38.65	33.14
WALNUT	0	54.89	0.876	48.09	8.07	2.74	2.21	46.29	39.48	0.00	49.03	42.23
MILO*(cover)	35	24.67	0.876	21.61	6.38	0.62	0.86	18.54	15.48	0.00	19.16	16.10

TABLE A-63 - Firebaugh Canal Water District - 1983 Data

1983 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

57.06 inches = ANNUAL ETo
15.23 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.42	1.000	3.42	7.02	0.00	-0.18	0.00	0.00	0.00	0.00	0.00
MISC	0	15.29	0.876	13.40	8.04	0.00	0.36	7.61	5.72	0.00	7.61	5.72
COTTON	4989	30.25	0.876	26.50	9.34	1.51	1.04	20.44	16.69	0.00	21.95	18.20
ALFALFA	935	55.99	0.876	49.05	11.97	2.80	2.08	43.31	36.36	0.00	46.10	39.16
WHEAT	3481	15.64	0.876	13.70	10.55	0.39	0.24	4.94	3.00	0.00	5.33	3.39
MELONS	0	15.36	0.876	13.45	5.26	0.38	0.50	10.21	8.31	0.00	10.59	8.69
TOMATOES	0	29.95	0.876	26.24	9.38	1.50	1.02	20.09	16.38	0.00	21.59	17.88
SUGARBEET	1674	40.59	0.876	35.56	10.46	2.03	1.46	29.56	24.52	0.00	31.59	26.55
BARLEY	0	13.30	0.876	11.65	10.55	0.33	0.13	2.55	0.90	0.00	2.88	1.23
BEANS	0	23.49	0.876	20.58	6.07	0.59	0.86	17.70	14.79	0.00	18.29	15.38
SD ALFALFA	0	38.70	0.876	33.90	10.55	1.94	1.33	27.55	22.75	0.00	29.48	24.68
RICE	3057	45.81	0.876	40.13	9.97	2.29	1.69	35.24	29.56	0.00	37.53	31.85
CORN	157	31.17	0.876	27.30	9.38	0.78	1.08	22.09	18.22	0.00	22.87	19.00
VEGETABLE	1763	15.29	0.876	13.40	8.04	0.00	0.36	7.61	5.72	0.00	7.61	5.72
PASTURE	0	51.35	0.876	44.99	11.97	2.57	1.86	38.68	32.31	0.00	41.25	34.88
ALMOND-STONE	0	46.29	0.876	40.55	10.65	2.31	1.69	35.01	29.27	0.00	37.33	31.59
WALNUT	0	56.92	0.876	49.86	10.96	2.85	2.17	45.29	38.23	0.00	48.13	41.08
MILO*(cover)	728	26.56	0.876	23.27	8.02	0.66	0.92	18.80	15.51	0.00	19.46	16.17

TABLE A-64 - Firebaugh Canal Water District - 1984 Data

1984 DATA   0.54 dS/m = DELIVERED WATER QUALITY   60.03 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe   6.35 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.62	1.000	3.62	3.82	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
MISC	0	17.76	0.876	15.56	4.47	0.00	0.63	13.92	11.72	0.00	13.92	11.72
COTTON	11671	28.95	0.876	25.36	3.87	1.45	1.19	24.82	21.23	0.00	26.27	22.68
ALFALFA	964	58.68	0.876	51.41	5.48	2.93	2.52	52.79	45.51	0.00	55.73	48.45
WHEAT	3823	19.14	0.876	16.76	4.52	0.48	0.69	14.83	12.46	0.00	15.31	12.94
MELONS	0	14.68	0.876	12.86	3.88	0.37	0.52	10.95	9.13	0.00	11.31	9.49
TOMATOES	0	28.42	0.876	24.90	3.88	1.42	1.16	24.28	20.76	0.00	25.70	22.18
SUGARBEET	1459	40.05	0.876	35.08	4.51	2.00	1.68	35.22	30.25	0.00	37.22	32.26
BARLEY	0	16.28	0.876	14.26	4.52	0.41	0.56	11.91	9.89	0.00	12.32	10.30
BEANS	0	22.25	0.876	19.49	3.87	0.56	0.87	18.70	15.94	0.00	19.25	16.50
SD ALFALFA	0	40.59	0.876	35.55	4.56	2.03	1.70	35.70	30.67	0.00	37.73	32.70
RICE	1691	45.86	0.876	40.17	4.13	2.29	1.97	41.41	35.73	0.00	43.71	38.02
CORN	0	29.59	0.876	25.92	3.87	0.74	1.22	26.20	22.53	0.00	26.94	23.27
VEGETABLE	1083	17.76	0.876	15.56	4.47	0.00	0.63	13.92	11.72	0.00	13.92	11.72
PASTURE	0	54.27	0.876	47.54	5.48	2.71	2.31	48.39	41.66	0.00	51.10	44.37
ALMOND-STONE	0	46.66	0.876	40.88	4.40	2.33	2.00	41.93	36.14	0.00	44.26	38.47
WALNUT	0	57.54	0.876	50.40	4.69	2.88	2.50	52.47	45.33	0.00	55.35	48.21
MILO	0	25.39	0.876	22.24	3.87	0.63	1.02	21.91	18.76	0.00	22.54	19.39

TABLE A-65 - Firebaugh Canal Water District - 1985 Data

1985 DATA 0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

56.66 inches = ANNUAL ETo
6.07 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.40	1.000	3.40	3.44	0.00	-0.00	0.00	0.00	0.00	0.00	0.00
MISC	0	16.72	0.876	14.65	3.86	0.00	0.61	13.47	11.39	0.00	13.47	11.39
COTTON	10699	27.83	0.876	24.38	3.46	1.39	1.15	24.13	20.68	0.00	25.52	22.07
ALFALFA	992	55.59	0.876	48.70	5.00	2.78	2.39	50.21	43.31	0.00	52.98	46.09
WHEAT	2941	17.91	0.876	15.69	4.16	0.45	0.65	13.95	11.73	0.00	14.40	12.18
MELONS	942	14.01	0.876	12.27	3.53	0.35	0.50	10.62	8.89	0.00	10.97	9.24
TOMATOES	0	27.58	0.876	24.16	3.53	1.38	1.14	23.81	20.39	0.00	25.19	21.77
SUGARBEET	2759	38.38	0.876	33.62	3.89	1.92	1.63	34.20	29.44	0.00	36.12	31.36
BARLEY	0	15.24	0.876	13.35	4.16	0.38	0.52	11.22	9.33	0.00	11.60	9.71
BEANS	0	21.12	0.876	18.50	3.46	0.53	0.84	17.97	15.35	0.00	18.49	15.88
SD ALFALFA	0	38.43	0.876	33.67	4.19	1.92	1.62	33.94	29.18	0.00	35.86	31.10
RICE	649	43.82	0.876	38.39	3.84	2.19	1.89	39.67	34.24	0.00	41.87	36.43
CORN	0	28.48	0.876	24.95	3.46	0.71	1.18	25.49	21.95	0.00	26.20	22.67
VEGETABLE	749	16.72	0.876	14.65	3.86	0.00	0.61	13.47	11.39	0.00	13.47	11.39
PASTURE	0	50.99	0.876	44.67	5.00	2.55	2.18	45.62	39.30	0.00	48.17	41.85
ALMOND-STONE	0	44.34	0.876	38.84	4.09	2.22	1.90	39.94	34.44	0.00	42.15	36.66
WALNUT	0	54.80	0.876	48.01	4.17	2.74	2.39	50.29	43.50	0.00	53.03	46.24
MILO	0	24.37	0.876	21.35	3.46	0.61	0.99	21.28	18.26	0.00	21.89	18.87

TABLE A-66 - Firebaugh Canal Water District - 1986 Data

1986 DATA 0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

55.46 inches = ANNUAL ETo
6.81 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	0	3.33	1.000	3.33	4.28	0.00	-0.05	0.00	0.00	0.00	0.00	0.00
MISC	0	15.56	0.876	13.63	5.36	0.00	0.48	10.69	8.76	0.00	10.69	8.76
COTTON	7371	26.99	0.876	23.64	4.57	1.35	1.06	22.13	18.78	0.00	23.48	20.13
ALFALFA	1218	54.20	0.876	47.48	5.77	2.71	2.29	48.01	41.29	0.00	50.72	44.00
WHEAT	3587	16.76	0.876	14.68	5.41	0.42	0.54	11.46	9.38	0.00	11.88	9.80
MELONS	1269	13.32	0.876	11.66	4.60	0.33	0.43	8.82	7.16	0.00	9.15	7.50
TOMATOES	0	26.66	0.876	23.36	4.65	1.33	1.04	21.73	18.42	0.00	23.06	19.75
SUGARBEET	2823	36.74	0.876	32.18	5.36	1.84	1.48	31.02	26.47	0.00	32.86	28.31
BARLEY	0	14.31	0.876	12.54	5.41	0.36	0.42	8.96	7.19	0.00	9.32	7.54
BEANS	0	20.17	0.876	17.67	4.39	0.50	0.75	16.02	13.52	0.00	16.53	14.03
SD ALFALFA	0	36.58	0.876	32.05	5.41	1.83	1.47	30.81	26.28	0.00	32.64	28.11
RICE	1240	41.88	0.876	36.69	4.97	2.09	1.75	36.56	31.37	0.00	38.65	33.46
CORN	1269	27.56	0.876	24.15	4.57	0.69	1.09	23.39	19.97	0.00	24.08	20.66
VEGETABLE	811	15.56	0.876	13.63	5.36	0.00	0.48	10.69	8.76	0.00	10.69	8.76
PASTURE	0	49.91	0.876	43.72	5.77	2.50	2.09	43.74	37.55	0.00	46.23	40.04
ALMOND-STONE	0	42.69	0.876	37.40	5.15	2.13	1.78	37.18	31.89	0.00	39.32	34.02
WALNUT	0	53.15	0.876	46.56	5.15	2.66	2.27	47.61	41.02	0.00	50.27	43.68
MILO*(cover)	237	23.64	0.876	20.71	4.57	0.59	0.90	19.38	16.44	0.00	19.97	17.04

TABLE A-67 - Firebaugh Canal Water District - 1987 Data

1987 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

56.84 inches = ANNUAL ETo
7.96 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.41	1.000	3.41	4.62	0.00	-0.06	0.00	0.00	0.00	0.00	0.00
MISC	0	16.98	0.876	14.87	5.55	0.00	0.54	11.96	9.86	0.00	11.96	9.86
COTTON	8983	27.60	0.876	24.18	4.74	1.38	1.08	22.56	19.14	0.00	23.94	20.52
ALFALFA	1692	55.29	0.876	48.43	6.91	2.76	2.29	47.90	41.04	0.00	50.66	43.81
WHEAT	3083	18.18	0.876	15.92	5.86	0.45	0.58	12.44	10.19	0.00	12.89	10.64
MELONS	1378	13.91	0.876	12.19	4.19	0.35	0.48	9.86	8.13	0.00	10.21	8.48
TOMATOES	0	27.43	0.876	24.02	4.74	1.37	1.07	22.38	18.98	0.00	23.76	20.35
SUGARBEET	3463	38.34	0.876	33.58	5.55	1.92	1.55	32.42	27.67	0.00	34.34	29.58
BARLEY	0	15.46	0.876	13.54	5.86	0.39	0.45	9.66	7.74	0.00	10.04	8.13
BEANS	0	20.99	0.876	18.39	4.74	0.52	0.77	16.49	13.89	0.00	17.01	14.41
SD ALFALFA	0	38.49	0.876	33.72	5.86	1.92	1.54	32.24	27.47	0.00	34.17	29.39
RICE	1143	44.05	0.876	38.58	5.03	2.20	1.84	38.66	33.20	0.00	40.86	35.40
CORN	0	28.27	0.876	24.76	4.74	0.71	1.11	23.93	20.42	0.00	24.63	21.13
VEGETABLE	565	16.98	0.876	14.87	5.55	0.00	0.54	11.96	9.86	0.00	11.96	9.86
PASTURE	0	51.16	0.876	44.81	6.91	2.56	2.09	43.78	37.43	0.00	46.33	39.99
ALMOND-STONE	0	44.29	0.876	38.80	5.44	2.21	1.84	38.47	32.97	0.00	40.68	35.19
WALNUT	0	54.58	0.876	47.81	5.74	2.73	2.31	48.42	41.65	0.00	51.15	44.38
MILO*(cover)	634	24.19	0.876	21.19	4.74	0.60	0.92	19.76	16.76	0.00	20.37	17.37

TABLE A-68 - Firebaugh Canal Water District - 1988 Data

1988 DATA 0.54 dS/m = DELIVERED WATER QUALITY 55.02 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 6.24 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.30	1.000	3.30	3.51	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
MISC	0	16.16	0.876	14.16	4.29	0.00	0.56	12.43	10.43	0.00	12.43	10.43
COTTON	11851	26.46	0.876	23.18	3.66	1.32	1.08	22.56	19.28	0.00	23.88	20.60
ALFALFA	1834	53.77	0.876	47.10	5.24	2.69	2.29	48.14	41.47	0.00	50.83	44.16
WHEAT	2311	18.57	0.876	16.27	4.62	0.46	0.66	14.15	11.85	0.00	14.61	12.31
MELONS	1607	12.83	0.876	11.24	3.97	0.32	0.42	8.96	7.37	0.00	9.28	7.69
TOMATOES	710	26.09	0.876	22.85	3.97	1.30	1.05	21.86	18.62	0.00	23.16	19.93
SUGARBEET	2499	36.19	0.876	31.70	4.29	1.81	1.51	31.60	27.11	0.00	33.41	28.92
BARLEY	0	15.79	0.876	13.83	4.62	0.39	0.53	11.31	9.35	0.00	11.70	9.74
BEANS	0	19.65	0.876	17.21	3.66	0.49	0.76	16.25	13.82	0.00	16.74	14.31
SD ALFALFA	0	37.62	0.876	32.95	4.62	1.88	1.56	32.68	28.02	0.00	34.56	29.90
RICE	1287	41.62	0.876	36.46	4.06	2.08	1.78	37.25	32.09	0.00	39.33	34.17
CORN	0	27.03	0.876	23.68	3.66	0.68	1.10	23.79	20.44	0.00	24.47	21.12
VEGETABLE	66	16.16	0.876	14.16	4.29	0.00	0.56	12.43	10.43	0.00	12.43	10.43
PASTURE	0	49.52	0.876	43.38	5.24	2.48	2.09	43.90	37.76	0.00	46.38	40.24
ALMOND-STONE	40	41.96	0.876	36.75	4.06	2.10	1.79	37.59	32.38	0.00	39.68	34.48
WALNUT	0	51.64	0.876	45.23	4.40	2.58	2.23	46.89	40.49	0.00	49.47	43.07
MILO*(cover)	1077	23.38	0.876	20.48	3.66	0.58	0.93	20.07	17.17	0.00	20.65	17.75

TABLE A-69 - Firebaugh Canal Water District - 1989 Data

1989 DATA 0.54 dS/m = DELIVERED WATER QUALITY 57.65 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 2.54 inches = ANNUAL PPT

	1	2	3	4	5	6	7	8	9	10	11a	12a
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/O GW UNADJUST. ETc	WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	0	3.46	1.000	3.46	2.44	0.00	0.05	1.07	1.07	0.00	1.07	1.07
MISC	0	16.12	0.876	14.12	3.31	0.00	0.61	13.41	11.42	0.00	13.41	11.42
COTTON	10112	28.69	0.876	25.13	2.86	1.43	1.22	25.62	22.06	0.00	27.05	23.49
ALFALFA	2119	56.17	0.876	49.20	4.30	2.81	2.45	51.51	44.55	0.00	54.32	47.35
WHEAT	3864	17.37	0.876	15.22	3.45	0.43	0.66	14.14	11.99	0.00	14.58	12.42
MELONS	1953	14.24	0.876	12.47	2.55	0.36	0.55	11.88	10.11	0.00	12.24	10.47
TOMATOES	968	28.58	0.876	25.04	2.55	1.43	1.23	25.83	22.29	0.00	27.26	23.71
SUGARBEET	3115	39.10	0.876	34.25	3.31	1.96	1.69	35.53	30.68	0.00	37.49	32.64
BARLEY	0	14.80	0.876	12.97	3.45	0.37	0.54	11.51	9.68	0.00	11.88	10.05
BEANS	0	21.72	0.876	19.03	2.49	0.54	0.91	19.60	16.90	0.00	20.14	17.45
SD ALFALFA	0	38.65	0.876	33.86	3.45	1.93	1.66	34.93	30.13	0.00	36.86	32.07
RICE	601	44.69	0.876	39.15	2.99	2.23	1.97	41.43	35.89	0.00	43.67	38.13
CORN	0	29.44	0.876	25.79	2.86	0.74	1.26	27.10	23.45	0.00	27.84	24.19
VEGETABLE	620	16.12	0.876	14.12	3.31	0.00	0.61	13.41	11.42	0.00	13.41	11.42
PASTURE	0	51.89	0.876	45.45	4.30	2.59	2.25	47.24	40.80	0.00	49.83	43.40
ALMOND-STONE	40	44.94	0.876	39.37	3.69	2.25	1.95	40.96	35.39	0.00	43.21	37.64
WALNUT	0	55.61	0.876	48.72	3.84	2.78	2.45	51.44	44.54	0.00	54.22	47.32
MILO*(cover)	1354	25.19	0.876	22.06	2.86	0.63	1.06	22.75	19.63	0.00	23.38	20.26

TABLE A-70 - Panoche Water District - 1984 Data

1984 DATA 0.54 dS/m = DELIVERED WATER QUALITY 60.03 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 6.35 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/ GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	869	3.62	1.000	3.62	3.82	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
MISC	188	17.76	0.876	15.56	4.47	0.00	0.63	13.92	11.72	0.00	13.92	11.72
COTTON	15331	28.95	0.876	25.36	3.87	1.45	1.19	24.82	21.23	0.00	26.27	22.68
ALFALFA	1543	58.68	0.876	51.41	5.48	2.93	2.52	52.79	45.51	0.00	55.73	48.45
WHEAT	2823	19.14	0.876	16.76	4.52	0.48	0.69	14.83	12.46	0.00	15.31	12.94
MELONS	3984	14.68	0.876	12.86	3.88	0.37	0.52	10.95	9.13	0.00	11.31	9.49
TOMATOES	3804	28.42	0.876	24.90	3.88	1.42	1.16	24.28	20.76	0.00	25.70	22.18
SUGARBEET	1027	40.05	0.876	35.08	4.51	2.00	1.68	35.22	30.25	0.00	37.22	32.26
BARLEY	230	16.28	0.876	14.26	4.52	0.41	0.56	11.91	9.89	0.00	12.32	10.30
BEANS	1339	22.25	0.876	19.49	3.87	0.56	0.87	18.70	15.94	0.00	19.25	16.50
SD ALFALFA	0	40.59	0.876	35.55	4.56	2.03	1.70	35.70	30.67	0.00	37.73	32.70
RICE	0	45.86	0.876	40.17	4.13	2.29	1.97	41.41	35.73	0.00	43.71	38.02
CORN	150	29.59	0.876	25.92	3.87	1.48	1.22	25.46	21.79	0.00	26.94	23.27
VEGETABLE	1017	17.76	0.876	15.56	4.47	0.00	0.63	13.92	11.72	0.00	13.92	11.72
PASTURE	680	54.27	0.876	47.54	5.48	2.71	2.31	48.39	41.66	0.00	51.10	44.37
ALMOND-STONE	301	46.66	0.876	40.88	4.40	2.33	2.00	41.93	36.14	0.00	44.26	38.47
WALNUT	32	57.54	0.876	50.40	4.69	2.88	2.50	52.47	45.33	0.00	55.35	48.21
MILO	926	25.39	0.876	22.24	3.87	0.63	1.02	21.91	18.76	0.00	22.54	19.39

TABLE A-71 - Panoche Water District - 1985 Data

1985 DATA 0.54 dS/m = DELIVERED WATER QUALITY 56.66 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 6.07 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/ GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	869	3.40	1.000	3.40	3.44	0.00	-0.00	0.00	0.00	0.00	0.00	0.00
MISC	188	16.72	0.876	14.65	3.86	0.00	0.61	13.47	11.39	0.00	13.47	11.39
COTTON	15331	27.83	0.876	24.38	3.46	1.39	1.15	24.13	20.68	0.00	25.52	22.07
ALFALFA	1543	55.59	0.876	48.70	5.00	2.78	2.39	50.21	43.31	0.00	52.98	46.09
WHEAT	2823	17.91	0.876	15.69	4.16	0.45	0.65	13.95	11.73	0.00	14.40	12.18
MELONS	3984	14.01	0.876	12.27	3.53	0.35	0.50	10.62	8.89	0.00	10.97	9.24
TOMATOES	3804	27.58	0.876	24.16	3.53	1.38	1.14	23.81	20.39	0.00	25.19	21.77
SUGARBEET	1027	38.38	0.876	33.62	3.89	1.92	1.63	34.20	29.44	0.00	36.12	31.36
BARLEY	230	15.24	0.876	13.35	4.16	0.38	0.52	11.22	9.33	0.00	11.60	9.71
BEANS	1339	21.12	0.876	18.50	3.46	0.53	0.84	17.97	15.35	0.00	18.49	15.88
SD ALFALFA	0	38.43	0.876	33.67	4.19	1.92	1.62	33.94	29.18	0.00	35.86	31.10
RICE	0	43.82	0.876	38.39	3.84	2.19	1.89	39.67	34.24	0.00	41.87	36.43
CORN	150	28.48	0.876	24.95	3.46	1.42	1.18	24.77	21.24	0.00	26.20	22.67
VEGETABLE	1017	16.72	0.876	14.65	3.86	0.00	0.61	13.47	11.39	0.00	13.47	11.39
PASTURE	680	50.99	0.876	44.67	5.00	2.55	2.18	45.62	39.30	0.00	48.17	41.85
ALMOND-STONE	301	44.34	0.876	38.84	4.09	2.22	1.90	39.94	34.44	0.00	42.15	36.66
WALNUT	32	54.80	0.876	48.01	4.17	2.74	2.39	50.29	43.50	0.00	53.03	46.24
MILO	926	24.37	0.876	21.35	3.46	0.61	0.99	21.28	18.26	0.00	21.89	18.87

TABLE A-72 - Panoche Water District - 1986 Data

1986 DATA 0.54 dS/m = DELIVERED WATER QUALITY 55.46 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 6.81 inches = ANNUAL PPT

	1	2	3	4	5	6	7	8	9	10	11a	12a
CROPS	ACRES	ETc UNADJUSTED	Kc ADJ FACTOR	ETc ADJUSTED	EFFECTIVE PPT	NET EXTERNAL GW CONTRIB.	NET LEACHING	NET WATER REQ. UNADJUST. ETc	NET WATER REQ. ADJUST. ETc	RECLAMATn LEACHING	WATER REQ W/ GW UNADJUST. ETc	WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	1468	3.33	1.000	3.33	4.28	0.00	-0.05	0.00	0.00	0.00	0.00	0.00
MISC	0	15.56	0.876	13.63	5.36	0.00	0.48	10.69	8.76	0.00	10.69	8.76
COTTON	14924	26.99	0.876	23.64	4.57	1.35	1.06	22.13	18.78	0.00	23.48	20.13
ALFALFA	2464	54.20	0.876	47.48	5.77	2.71	2.29	48.01	41.29	0.00	50.72	44.00
WHEAT	2115	16.76	0.876	14.68	5.41	0.42	0.54	11.46	9.38	0.00	11.88	9.80
MELONS	2215	13.32	0.876	11.66	4.60	0.33	0.43	8.82	7.16	0.00	9.15	7.50
TOMATOES	4283	26.66	0.876	23.36	4.65	1.33	1.04	21.73	18.42	0.00	23.06	19.75
SUGARBEET	719	36.74	0.876	32.18	5.36	1.84	1.48	31.02	26.47	0.00	32.86	28.31
BARLEY	926	14.31	0.876	12.54	5.41	0.36	0.42	8.96	7.19	0.00	9.32	7.54
BEANS	2285	20.17	0.876	17.67	4.39	0.50	0.75	16.02	13.52	0.00	16.53	14.03
SD ALFALFA	300	36.58	0.876	32.05	5.41	1.83	1.47	30.81	26.28	0.00	32.64	28.11
RICE	0	41.88	0.876	36.69	4.97	2.09	1.75	36.56	31.37	0.00	38.65	33.46
CORN	949	27.56	0.876	24.15	4.57	1.38	1.09	22.70	19.28	0.00	24.08	20.66
VEGETABLE	335	15.56	0.876	13.63	5.36	0.00	0.48	10.69	8.76	0.00	10.69	8.76
PASTURE	45	49.91	0.876	43.72	5.77	2.50	2.09	43.74	37.55	0.00	46.23	40.04
ALMOND-STONE	317	42.69	0.876	37.40	5.15	2.13	1.78	37.18	31.89	0.00	39.32	34.02
WALNUT	250	53.15	0.876	46.56	5.15	2.66	2.27	47.61	41.02	0.00	50.27	43.68
MILO	1026	23.64	0.876	20.71	4.57	0.59	0.90	19.38	16.44	0.00	19.97	17.04

TABLE A-73 - Panoche Water District - 1987 Data

1987 DATA 0.54 dS/m = DELIVERED WATER QUALITY 56.84 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 7.96 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/ GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	798	3.41	1.000	3.41	4.62	0.00	-0.06	0.00	0.00	0.00	0.00	0.00
MISC	0	16.98	0.876	14.87	5.55	0.00	0.54	11.96	9.86	0.00	11.96	9.86
COTTON	14895	27.60	0.876	24.18	4.74	1.38	1.08	22.56	19.14	0.00	23.94	20.52
ALFALFA	2439	55.29	0.876	48.43	6.91	2.76	2.29	47.90	41.04	0.00	50.66	43.81
WHEAT	3622	18.18	0.876	15.92	5.86	0.45	0.58	12.44	10.19	0.00	12.89	10.64
MELONS	1193	13.91	0.876	12.19	4.19	0.35	0.48	9.86	8.13	0.00	10.21	8.48
TOMATOES	2550	27.43	0.876	24.02	4.74	1.37	1.07	22.38	18.98	0.00	23.76	20.35
SUGARBEET	1528	38.34	0.876	33.58	5.55	1.92	1.55	32.42	27.67	0.00	34.34	29.58
BARLEY	130	15.46	0.876	13.54	5.86	0.39	0.45	9.66	7.74	0.00	10.04	8.13
BEANS	302	20.99	0.876	18.39	4.74	0.52	0.77	16.49	13.89	0.00	17.01	14.41
SD ALFALFA	300	38.49	0.876	33.72	5.86	1.92	1.54	32.24	27.47	0.00	34.17	29.39
RICE	0	44.05	0.876	38.58	5.03	2.20	1.84	38.66	33.20	0.00	40.86	35.40
CORN	2576	28.27	0.876	24.76	4.74	1.41	1.11	23.22	19.72	0.00	24.63	21.13
VEGETABLE	2074	16.98	0.876	14.87	5.55	0.00	0.54	11.96	9.86	0.00	11.96	9.86
PASTURE	0	51.16	0.876	44.81	6.91	2.56	2.09	43.78	37.43	0.00	46.33	39.99
ALMOND-STONE	273	44.29	0.876	38.80	5.44	2.21	1.84	38.47	32.97	0.00	40.68	35.19
WALNUT	253	54.58	0.876	47.81	5.74	2.73	2.31	48.42	41.65	0.00	51.15	44.38
MILO	73	24.19	0.876	21.19	4.74	0.60	0.92	19.76	16.76	0.00	20.37	17.37

TABLE A-74 - Panoche Water District - 1988 Data

1988 DATA 0.54 dS/m = DELIVERED WATER QUALITY 55.02 inches = ANNUAL ETo
2.5 dS/m = THRESHHOLD ECe 6.24 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/ GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	852	3.30	1.000	3.30	3.51	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
MISC	277	16.16	0.876	14.16	4.29	0.00	0.56	12.43	10.43	0.00	12.43	10.43
COTTON	18560	26.46	0.876	23.18	3.66	1.32	1.08	22.56	19.28	0.00	23.88	20.60
ALFALFA	2853	53.77	0.876	47.10	5.24	2.69	2.29	48.14	41.47	0.00	50.83	44.16
WHEAT	837	18.57	0.876	16.27	4.62	0.46	0.66	14.15	11.85	0.00	14.61	12.31
MELONS	1504	12.83	0.876	11.24	3.97	0.32	0.42	8.96	7.37	0.00	9.28	7.69
TOMATOES	5478	26.09	0.876	22.85	3.97	1.30	1.05	21.86	18.62	0.00	23.16	19.93
SUGARBEET	219	36.19	0.876	31.70	4.29	1.81	1.51	31.60	27.11	0.00	33.41	28.92
BARLEY	0	15.79	0.876	13.83	4.62	0.39	0.53	11.31	9.35	0.00	11.70	9.74
BEANS	0	19.65	0.876	17.21	3.66	0.49	0.76	16.25	13.82	0.00	16.74	14.31
SD ALFALFA	155	37.62	0.876	32.95	4.62	1.88	1.56	32.68	28.02	0.00	34.56	29.90
RICE	0	41.62	0.876	36.46	4.06	2.08	1.78	37.25	32.09	0.00	39.33	34.17
CORN	545	27.03	0.876	23.68	3.66	1.35	1.10	23.12	19.77	0.00	24.47	21.12
VEGETABLE	1935	16.16	0.876	14.16	4.29	0.00	0.56	12.43	10.43	0.00	12.43	10.43
PASTURE	1122	49.52	0.876	43.38	5.24	2.48	2.09	43.90	37.76	0.00	46.38	40.24
ALMOND-STONE	58	41.96	0.876	36.75	4.06	2.10	1.79	37.59	32.38	0.00	39.68	34.48
WALNUT	252	51.64	0.876	45.23	4.40	2.58	2.23	46.89	40.49	0.00	49.47	43.07
MILO	0	23.38	0.876	20.48	3.66	0.58	0.93	20.07	17.17	0.00	20.65	17.75

TABLE A-75 - Panoche Water District - 1989 Data

1989 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

57.65 inches = ANNUAL ETo
2.54 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/ GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	1029	3.46	1.000	3.46	2.44	0.00	0.05	1.07	1.07	0.00	1.07	1.07
MISC	0	16.12	0.876	14.12	3.31	0.00	0.61	13.41	11.42	0.00	13.41	11.42
COTTON	15239	28.69	0.876	25.13	2.86	1.43	1.22	25.62	22.06	0.00	27.05	23.49
ALFALFA	2999	56.17	0.876	49.20	4.30	2.81	2.45	51.51	44.55	0.00	54.32	47.35
WHEAT	3451	17.37	0.876	15.22	3.45	0.43	0.66	14.14	11.99	0.00	14.58	12.42
MELONS	3282	14.24	0.876	12.47	2.55	0.36	0.55	11.88	10.11	0.00	12.24	10.47
TOMATOES	5401	28.58	0.876	25.04	2.55	1.43	1.23	25.83	22.29	0.00	27.26	23.71
SUGARBEET	220	39.10	0.876	34.25	3.31	1.96	1.69	35.53	30.68	0.00	37.49	32.64
BARLEY	0	14.80	0.876	12.97	3.45	0.37	0.54	11.51	9.68	0.00	11.88	10.05
BEANS	2712	21.72	0.876	19.03	2.49	0.54	0.91	19.60	16.90	0.00	20.14	17.45
SD ALFALFA	0	38.65	0.876	33.86	3.45	1.93	1.66	34.93	30.13	0.00	36.86	32.07
RICE	0	44.69	0.876	39.15	2.99	2.23	1.97	41.43	35.89	0.00	43.67	38.13
CORN	699	29.44	0.876	25.79	2.86	1.47	1.26	26.37	22.72	0.00	27.84	24.19
VEGETABLE	1188	16.12	0.876	14.12	3.31	0.00	0.61	13.41	11.42	0.00	13.41	11.42
PASTURE	26	51.89	0.876	45.45	4.30	2.59	2.25	47.24	40.80	0.00	49.83	43.40
ALMOND-STONE	217	44.94	0.876	39.37	3.69	2.25	1.95	40.96	35.39	0.00	43.21	37.64
WALNUT	252	55.61	0.876	48.72	3.84	2.78	2.45	51.44	44.54	0.00	54.22	47.32
MILO	0	25.19	0.876	22.06	2.86	0.63	1.06	22.75	19.63	0.00	23.38	20.26

TABLE A-76 - Pacheco Water District - 1984 Data

1984 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

60.03 inches = ANNUAL ETo
6.35 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	622	3.62	1.000	3.62	3.44	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
MISC	0	17.76	0.876	15.56	4.02	0.00	0.63	14.37	12.16	0.00	14.37	12.16
COTTON	2271	28.95	0.876	25.36	3.48	1.45	1.19	25.21	21.62	0.00	26.66	23.07
ALFALFA	165	58.68	0.876	51.41	4.93	2.93	2.52	53.34	46.06	0.00	56.27	49.00
WHEAT	60	19.14	0.876	16.76	4.06	0.48	0.69	15.28	12.91	0.00	15.76	13.39
MELONS	0	14.68	0.876	12.86	3.49	0.37	0.52	11.33	9.51	0.00	11.70	9.88
TOMATOES	0	28.42	0.876	24.90	3.49	1.42	1.16	24.67	21.15	0.00	26.09	22.57
SUGARBEET	0	40.05	0.876	35.08	4.06	2.00	1.68	35.67	30.70	0.00	37.67	32.71
BARLEY	0	16.28	0.876	14.26	4.06	0.41	0.56	12.36	10.34	0.00	12.77	10.75
BEANS	702	22.25	0.876	19.49	3.48	0.56	0.87	19.09	16.33	0.00	19.64	16.88
SD ALFALFA	0	40.59	0.876	35.55	4.10	2.03	1.70	36.16	31.13	0.00	38.19	33.16
RICE	0	45.86	0.876	40.17	3.71	2.29	1.97	41.83	36.14	0.00	44.12	38.43
CORN	0	29.59	0.876	25.92	3.48	1.48	1.22	25.84	22.17	0.00	27.32	23.65
VEGETABLE	98	17.76	0.876	15.56	4.02	0.00	0.63	14.37	12.16	0.00	14.37	12.16
PASTURE	0	54.27	0.876	47.54	4.93	2.71	2.31	48.94	42.21	0.00	51.65	44.92
ALMOND-STONE	400	46.66	0.876	40.88	3.96	2.33	2.00	42.37	36.58	0.00	44.70	38.91
WALNUT	0	57.54	0.876	50.40	4.22	2.88	2.50	52.94	45.80	0.00	55.81	48.68
MILO	0	25.39	0.876	22.24	3.48	0.63	1.02	22.29	19.14	0.00	22.93	19.78

TABLE A-77 - Pacheco Water District - 1985 Data

1985 DATA   0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

56.66 inches = ANNUAL ETo
6.07 inches = ANNUAL PPT

CROPS	1 ACRES	2 ETc UNADJUSTED	3 Kc ADJ FACTOR	4 ETc ADJUSTED	5 EFFECTIVE PPT	6 NET EXTERNAL GW CONTRIB.	7 NET LEACHING	8 NET WATER REQ. UNADJUST. ETc	9 NET WATER REQ. ADJUST. ETc	10 RECLAMATn LEACHING	11a WATER REQ W/O GW UNADJUST. ETc	12a WATER REQ W/O GW ADJUST. ETc
	Ac	In		In	In	In	In	In	In	In	In	In
FALLOW	1120	3.40	1.000	3.40	3.09	0.00	-0.00	0.00	0.00	0.00	0.00	0.00
MISC	0	16.72	0.876	14.65	3.48	0.00	0.61	13.85	11.78	0.00	13.85	11.78
COTTON	2263	27.83	0.876	24.38	3.12	1.39	1.15	24.47	21.02	0.00	25.87	22.41
ALFALFA	162	55.59	0.876	48.70	4.50	2.78	2.39	50.71	43.81	0.00	53.48	46.59
WHEAT	0	17.91	0.876	15.69	3.75	0.45	0.65	14.37	12.15	0.00	14.82	12.60
MELONS	675	14.01	0.876	12.27	3.18	0.35	0.50	10.98	9.24	0.00	11.33	9.59
TOMATOES	0	27.58	0.876	24.16	3.18	1.38	1.14	24.16	20.74	0.00	25.54	22.12
SUGARBEET	0	38.38	0.876	33.62	3.50	1.92	1.63	34.59	29.83	0.00	36.51	31.75
BARLEY	0	15.24	0.876	13.35	3.75	0.38	0.52	11.64	9.75	0.00	12.02	10.13
BEANS	0	21.12	0.876	18.50	3.12	0.53	0.84	18.31	15.69	0.00	18.84	16.22
SD ALFALFA	0	38.43	0.876	33.67	3.77	1.92	1.62	34.36	29.59	0.00	36.28	31.52
RICE	0	43.82	0.876	38.39	3.46	2.19	1.89	40.06	34.63	0.00	42.25	36.82
CORN	0	28.48	0.876	24.95	3.12	1.42	1.18	25.12	21.59	0.00	26.54	23.01
VEGETABLE	0	16.72	0.876	14.65	3.48	0.00	0.61	13.85	11.78	0.00	13.85	11.78
PASTURE	0	50.99	0.876	44.67	4.50	2.55	2.18	46.12	39.80	0.00	48.67	42.35
ALMOND-STONE	0	44.34	0.876	38.84	3.68	2.22	1.90	40.35	34.85	0.00	42.56	37.06
WALNUT	0	54.80	0.876	48.01	3.75	2.74	2.39	50.71	43.91	0.00	53.45	46.65
MILO	0	24.37	0.876	21.35	3.12	0.61	0.99	21.63	18.61	0.00	22.24	19.22

TABLE A-78 - Pacheco Water District - 1986 Data

1986 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

55.46 inches = ANNUAL ETo
6.81 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	720	3.33	1.000	3.33	3.86	0.00	-0.05	0.00	0.00	0.00	0.00	0.00
MISC	0	15.56	0.876	13.63	4.82	0.00	0.48	11.22	9.29	0.00	11.22	9.29
COTTON	2076	26.99	0.876	23.64	4.11	1.35	1.06	22.59	19.24	0.00	23.94	20.59
ALFALFA	160	54.20	0.876	47.48	5.19	2.71	2.29	48.59	41.87	0.00	51.30	44.58
WHEAT	0	16.76	0.876	14.68	4.87	0.42	0.54	12.00	9.93	0.00	12.42	10.34
MELONS	1057	13.32	0.876	11.66	4.14	0.33	0.43	9.28	7.62	0.00	9.61	7.96
TOMATOES	0	26.66	0.876	23.36	4.18	1.33	1.04	22.19	18.88	0.00	23.52	20.22
SUGARBEET	0	36.74	0.876	32.18	4.82	1.84	1.48	31.56	27.00	0.00	33.40	28.84
BARLEY	0	14.31	0.876	12.54	4.87	0.36	0.42	9.50	7.73	0.00	9.86	8.09
BEANS	0	20.17	0.876	17.67	3.95	0.50	0.75	16.46	13.96	0.00	16.97	14.47
SD ALFALFA	0	36.58	0.876	32.05	4.87	1.83	1.47	31.36	26.82	0.00	33.18	28.65
RICE	0	41.88	0.876	36.69	4.47	2.09	1.75	37.06	31.86	0.00	39.15	33.96
CORN	0	27.56	0.876	24.15	4.11	1.38	1.09	23.16	19.74	0.00	24.54	21.12
VEGETABLE	0	15.56	0.876	13.63	4.82	0.00	0.48	11.22	9.29	0.00	11.22	9.29
PASTURE	0	49.91	0.876	43.72	5.19	2.50	2.09	44.31	38.12	0.00	46.81	40.62
ALMOND-STONE	0	42.69	0.876	37.40	4.64	2.13	1.78	37.70	32.40	0.00	39.83	34.54
WALNUT	0	53.15	0.876	46.56	4.64	2.66	2.27	48.13	41.54	0.00	50.79	44.20
MILO	0	23.64	0.876	20.71	4.11	0.59	0.90	19.83	16.90	0.00	20.42	17.49

TABLE A-79 - Pacheco Water District - 1987 Data

1987 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

56.84 inches = ANNUAL ETo
7.96 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	802	3.41	1.000	3.41	4.16	0.00	-0.06	0.00	0.00	0.00	0.00	0.00
MISC	0	16.98	0.876	14.87	5.00	0.00	0.54	12.52	10.41	0.00	12.52	10.41
COTTON	2194	27.60	0.876	24.18	4.27	1.38	1.08	23.03	19.61	0.00	24.41	20.99
ALFALFA	330	55.29	0.876	48.43	6.22	2.76	2.29	48.59	41.73	0.00	51.35	44.50
WHEAT	20	18.18	0.876	15.92	5.28	0.45	0.58	13.03	10.77	0.00	13.48	11.23
MELONS	823	13.91	0.876	12.19	3.77	0.35	0.48	10.28	8.55	0.00	10.63	8.90
TOMATOES	0	27.43	0.876	24.02	4.27	1.37	1.07	22.86	19.46	0.00	24.23	20.83
SUGARBEET	0	38.34	0.876	33.58	5.00	1.92	1.55	32.97	28.22	0.00	34.89	30.14
BARLEY	0	15.46	0.876	13.54	5.28	0.39	0.45	10.24	8.33	0.00	10.63	8.71
BEANS	0	20.99	0.876	18.39	4.27	0.52	0.77	16.96	14.36	0.00	17.49	14.89
SD ALFALFA	0	38.49	0.876	33.72	5.28	1.92	1.54	32.83	28.06	0.00	34.75	29.98
RICE	0	44.05	0.876	38.58	4.53	2.20	1.84	39.16	33.70	0.00	41.36	35.90
CORN	0	28.27	0.876	24.76	4.27	1.41	1.11	23.70	20.19	0.00	25.11	21.60
VEGETABLE	231	16.98	0.876	14.87	5.00	0.00	0.54	12.52	10.41	0.00	12.52	10.41
PASTURE	0	51.16	0.876	44.81	6.22	2.56	2.09	44.47	38.13	0.00	47.03	40.68
ALMOND-STONE	0	44.29	0.876	38.80	4.90	2.21	1.84	39.01	33.52	0.00	41.22	35.73
WALNUT	0	54.58	0.876	47.81	5.17	2.73	2.31	49.00	42.23	0.00	51.72	44.96
MILO	0	24.19	0.876	21.19	4.27	0.60	0.92	20.24	17.24	0.00	20.84	17.84

TABLE A-80 - Pacheco Water District - 1988 Data

1988 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

55.02 inches = ANNUAL ETo
6.24 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	321	3.30	1.000	3.30	3.16	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
MISC	0	16.16	0.876	14.16	3.86	0.00	0.56	12.86	10.86	0.00	12.86	10.86
COTTON	2320	26.46	0.876	23.18	3.30	1.32	1.08	22.92	19.64	0.00	24.25	20.97
ALFALFA	160	53.77	0.876	47.10	4.71	2.69	2.29	48.66	42.00	0.00	51.35	44.69
WHEAT	139	18.57	0.876	16.27	4.16	0.46	0.66	14.61	12.31	0.00	15.08	12.77
MELONS	966	12.83	0.876	11.24	3.58	0.32	0.42	9.36	7.77	0.00	9.68	8.09
TOMATOES	311	26.09	0.876	22.85	3.58	1.30	1.05	22.25	19.02	0.00	23.56	20.32
SUGARBEET	0	36.19	0.876	31.70	3.86	1.81	1.51	32.03	27.54	0.00	33.84	29.35
BARLEY	143	15.79	0.876	13.83	4.16	0.39	0.53	11.77	9.81	0.00	12.16	10.21
BEANS	0	19.65	0.876	17.21	3.30	0.49	0.76	16.62	14.18	0.00	17.11	14.67
SD ALFALFA	0	37.62	0.876	32.95	4.16	1.88	1.56	33.14	28.48	0.00	35.02	30.36
RICE	0	41.62	0.876	36.46	3.66	2.08	1.78	37.66	32.50	0.00	39.74	34.58
CORN	0	27.03	0.876	23.68	3.30	1.35	1.10	23.49	20.13	0.00	24.84	21.49
VEGETABLE	0	16.16	0.876	14.16	3.86	0.00	0.56	12.86	10.86	0.00	12.86	10.86
PASTURE	0	49.52	0.876	43.38	4.71	2.48	2.09	44.42	38.28	0.00	46.90	40.76
ALMOND-STONE	0	41.96	0.876	36.75	3.66	2.10	1.79	37.99	32.79	0.00	40.09	34.89
WALNUT	0	51.64	0.876	45.23	3.96	2.58	2.23	47.33	40.93	0.00	49.91	43.51
MILO	0	23.38	0.876	20.48	3.30	0.58	0.93	20.43	17.53	0.00	21.02	18.12

TABLE A-81 - Pacheco Water District - 1989 Data

1989 DATA

0.54 dS/m = DELIVERED WATER QUALITY
2.5 dS/m = THRESHHOLD ECe

57.65 inches = ANNUAL ETo
2.54 inches = ANNUAL PPT

CROPS	1 ACRES Ac	2 ETc UNADJUSTED In	3 Kc ADJ FACTOR	4 ETc ADJUSTED In	5 EFFECTIVE PPT In	6 NET EXTERNAL GW CONTRIB. In	7 NET LEACHING In	8 NET WATER REQ. UNADJUST. ETc In	9 NET WATER REQ. ADJUST. ETc In	10 RECLAMATn LEACHING In	11a WATER REQ W/O GW UNADJUST. ETc In	12a WATER REQ W/O GW ADJUST. ETc In
FALLOW	739	3.46	1.000	3.46	2.20	0.00	0.05	1.31	1.31	0.00	1.31	1.31
MISC	0	16.12	0.876	14.12	2.98	0.00	0.61	13.74	11.75	0.00	13.74	11.75
COTTON	2080	28.69	0.876	25.13	2.57	1.43	1.22	25.90	22.35	0.00	27.34	23.78
ALFALFA	167	56.17	0.876	49.20	3.87	2.81	2.45	51.94	44.98	0.00	54.75	47.78
WHEAT	268	17.37	0.876	15.22	3.11	0.43	0.66	14.49	12.33	0.00	14.92	12.77
MELONS	516	14.24	0.876	12.47	2.30	0.36	0.55	12.14	10.37	0.00	12.49	10.73
TOMATOES	210	28.58	0.876	25.04	2.30	1.43	1.23	26.08	22.54	0.00	27.51	23.97
SUGARBEET	0	39.10	0.876	34.25	2.98	1.96	1.69	35.86	31.01	0.00	37.82	32.97
BARLEY	127	14.80	0.876	12.97	3.11	0.37	0.54	11.86	10.02	0.00	12.23	10.39
BEANS	37	21.72	0.876	19.03	2.24	0.54	0.91	19.85	17.15	0.00	20.39	17.70
SD ALFALFA	0	38.65	0.876	33.86	3.11	1.93	1.66	35.27	30.48	0.00	37.20	32.41
RICE	0	44.69	0.876	39.15	2.69	2.23	1.97	41.73	36.19	0.00	43.97	38.43
CORN	0	29.44	0.876	25.79	2.57	1.47	1.26	26.65	23.00	0.00	28.13	24.48
VEGETABLE	0	16.12	0.876	14.12	2.98	0.00	0.61	13.74	11.75	0.00	13.74	11.75
PASTURE	0	51.89	0.876	45.45	3.87	2.59	2.25	47.67	41.23	0.00	50.26	43.83
ALMOND-STONE	0	44.94	0.876	39.37	3.32	2.25	1.95	41.33	35.76	0.00	43.58	38.01
WALNUT	0	55.61	0.876	48.72	3.46	2.78	2.45	51.82	44.93	0.00	54.60	47.71
MILO	0	25.19	0.876	22.06	2.57	0.63	1.06	23.04	19.92	0.00	23.67	20.54

REVIEW OF PERTINENT LITERATURE PROVIDING EFFICIENCY ESTIMATES

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INTRODUCTION

Overview

Pertinent literature was reviewed for evaluations of on-farm annual efficiencies in or near the Grasslands study area. There appear to be innumerable approaches to the determination or estimate of water destinations, to what is appropriately included in an efficiency term, and of course, to the terminology and abbreviations employed to convey the information. **Virtually none of the references cited herein employ the approach to annual on-farm efficiency used in other parts of this report--termed IE, or irrigation efficiency.** Therefore, within this section, the term "efficiency" refers to all approaches used. Note that in one instance a region-wide efficiency was estimated--this was included for purposes of comparison.

Following this overview, a Summary Table is given which consolidates the findings from the literature review. The Summary Table gives distinguishing characteristics of the efficiency terms utilized in each report, as well as the actual efficiency values. The six columns on the far right indicate whether or not the efficiency computations explicitly account for evaporation, effective rainfall, DU (distribution uniformity), timing, LR (leaching fraction), and shallow water table contributions. There are, of course, refinements which are ignored by the summary table, such as correctness of measured values like acreage or irrigation delivery amounts, or whether the report assumes the same ET and rainfall for every year, etc.

Following the Summary Table is an explanation of column heading, sub-heading, and field abbreviations.

The section entitled "Discussion of Pertinent References" provides sufficient information to more accurately assess each report's efficiency value(s) and methodologies. It is the information here that is summarized in the Summary Table.

The section entitled "Conclusion" attempts to explain, or account for, the differences seen in various reported efficiency values.

Summary Table:

Report	Area		Data Years	By Crop or Irr Sys		Efficiency			Computations Explicitly Account For					
	Name	Fields		Crop	Irr Sys	Area	Range	Ave	Evap	E Rn	DU	Time	LR	WTbl
Name	J.M. Montgomery Consulting Engineers Inc. and Boyle Engineering. 1990.													
Results	Subregion 10	NA	1980	All	All	Region	NA	**37%**		√				
Name	Boyle Engineering Corporation. 1986.													
Results	V. Westside	NA	1974	Alfalfa	All	On-farm	NA	**71%**		√				
	"	"	"	Melons	"	"	"	**33%**		√				
	"	"	"	Cotton	"	"	"	**69%**		√				
	"	"	"	D Orch	"	"	"	**85%**		√				
	"	"	"	Tomatoes	"	"	"	**73%**		√				
Name	Roos, Maurice. 1990.													
Results	DAU 216	NA	NA	All	All	On-farm	NA	**70%**		√	√	√	√	
Name	Ayars, James E. and G. Schrale. 1990.													
Results	Panoche WD	NA	1987	All	All	On-farm	29-141%	**72%**	√	√			√	
	"	"	"	Alfalfa	"	"	NA	**103%**	√	√			√	
	"	"	"	Cotton	"	"	NA	**87%**	√	√			√	
	"	"	"	Tomato	"	"	NA	**52%**	√	√			√	
	"	"	1988	All	"	"	NA	**78%**	√	√			√	
Name	Los Banos Resource Conservation District Mobile Lab. 1988.													
Results	NA	31	1988	All	All	On-farm	48-95%	**75%**		√			√	
	"	16	"	All	Furr/TW	"	NA	**70%**		√			√	
	"	9	"	All	Furr	"	NA	**73%**		√			√	
	"	5	"	All	Spr	"	NA	**80%**		√			√	
	"	1	"	All	Drip	"	NA	**73%**		√			√	
	"	11	"	Cotton	All	"	NA	**74%**		√			√	

Report	Area		Data Years	By Crop or Irr Sys		Efficiency			Computations Explicitly Account For					
	Name	Fields		Crop	Irr Sys	Area	Range	Ave	Evap	E Rn	DU	Time	LR	WTbl
	"	4	"	Tomato	All	"	NA	67%		√			√	
	Burt, Charles M. and K. Katen. 1988.													
Results	Westside RCD	83	1986-87	All	All	On-farm	33-100%	66%	√	√	√	√	√	P
	"	55	"	All	Furr	"	NA	62%	√	√	√	√	√	P
	"	2	"	All	Spr	"	NA	66%	√	√	√	√	√	P
	"	5	"	All	Drip	"	NA	87%	√	√	√	√	√	P
	"	NA	"	Cotton	All	"	NA	63%	√	√	√	√	√	P
	"	NA	"	Melons	All	"	NA	66%	√	√	√	√	√	P
	"	NA	"	S Beets	All	"	NA	60%	√	√	√	√	√	P
	"	NA	"	Tomato	All	"	NA	76%	√	√	√	√	√	P
Name	Westlands Water District. 1989.													
Results	WWD	335	1987-88	All	All	On-farm	NA	71%	√	√	√	√	√	P
	"	199	"	All	Furr	"	NA	69%	√	√	√	√	√	P
	"	82	"	All	Spr/Fur	"	NA	75%	√	√	√	√	√	P
	"	43	"	All	Spr	"	NA	72%	√	√	√	√	√	P
	"	11	"	All	Drip	"	NA	77%	√	√	√	√	√	P
	"	183	"	Cotton	All	"	NA	69%	√	√	√	√	√	P
	"	86	"	Tomato	All	"	NA	75%	√	√	√	√	√	P
	"	66	"	All Other	All	"	NA	69%	√	√	√	√	√	P
Name	Soil Conservation Service. 1990.													
Results	Grasslands Ar	57	1987-90	All	All	On-farm	37-100%	70%		√			√	
Name	California Department of Water Resources, USDA Soil Conservation Service, Shafter - Wasco RCD and Pond - Poso RCD. 1978.													
Results	Shafter/Wasco	7	1977	All	F & BS	On-farm	56-100%	77%		√			√	
Name	California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1980.													

Report	Area		Data Years	By Crop or Irr Sys		Efficiency			Computations Explicitly Account For					
	Name	Fields		Crop	Irr Sys	Area	Range	**Ave**	Evap	E Rn	DU	Time	LR	WTbl
Results	Shafter/Wasco	8	1978	All	F & BS	On-farm	31-100%	**63%**	√	√			√	
Name	California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1981.													
Results	Shafter/Wasco	9	1979	All	F & BS	On-farm	44-100%	**77%**	√	√				
Name	California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1984.													
Results	Shafter/Wasco	13	1980	All	F & BS	On-farm	44-100%	**70%**	√	√				
Name	California Department of Water Resources, USDA Soil Conservation Service and Pond - Shafter - Wasco RCD. 1985.													
Results	Shafter/Wasco	11	1981	All	F & BS	On-farm	56-100%	**75%**	√	√				
Name	California Department of Water Resources, USDA Soil Conservation Service and Pond - Shafter - Wasco RCD. 1988.													
Results	Shafter/Wasco	10	1983	All	F & BS	On-farm	34-100%	**72%**	√	√				

Summary Table Abbreviations

Note: Titles, sub-titles, and field values are shown in double quotes. Within fields, "NA" means either not available, or not applicable, and "√" is a check mark.

"Report": Identifies rows with report citation ("Name" in left column), and those rows with results ("Results" in left column).

"Area": Identifies study area name (under sub-title "Name") and the number of fields evaluated (under sub-title "Fields").

"Data Years": Identifies years during which field efficiency evaluations occurred.

"By Crop or Irr Sys": Indicates whether field evaluations of efficiency are grouped by a given crop (under sub-title "Crop") or irrigation system (under sub-title "Irr Sys").

"Efficiency": The sub-title "Area" refers to regional evaluations of efficiency ("Region") or on-farm evaluations ("On-farm"). The sub-title "Range" indicates the minimum and maximum efficiency values among all fields evaluated. "Ave" indicates the average efficiency among all fields evaluated; this column is in bold text for emphasis.

"Computations Explicitly Account For": The sub-titles refer to the efficiency components accounted for, if the field is checked ("√") or marked "P" (for partial consideration). The sub-title "Evap" refers to evaporation, "E Rn" refers to effective rain, "DU" refers to distribution uniformity, "Time" refers to timing of irrigations, "LR" refers to leaching requirement, and "WTbl" refers to uptake of water from a shallow water table. Note that how these terms are accounted for is not indicated. For example, there are a variety of approaches to assessing the leaching requirement.

DISCUSSION OF PERTINENT REFERENCES

J.M. Montgomery Consulting Engineers Inc. and Boyle Engineering. 1990.

Report Title: Central Valley Ground-Surface Water Model.

Data: The area of study which encompasses the Grasslands study area is Subregion 10, entitled the "Valley Floor west of San Joaquin River". The report subregions are equivalent to DWR's DSAs (Depletion Study Areas) when possible, and to subsections of the DSAs when necessary. In this case, Subregion 10 is the east third of DSA 49, entitled the "San Joaquin Basin".

The agricultural acreage within Subregion 10 is roughly 352,000 acres for the year 1980 (Figure 3.8 (d), "Agricultural Acreage for Subregion 10 (DSA 49A)").

The efficiency numerator (irrigation water beneficially used) was based on the report's determination of CUAW (consumptive use of applied water), which in turn was based on DWR's CU Model (where CU signifies consumptive use). The CU model uses precipitation, crop acreage, and crop evapotranspiration to determine the CUAW. For Subregion 10, the cropping pattern was based on 1980 data for DSA 49 by prorating.

The efficiency denominator (irrigation water applied) was based on surface diversions and groundwater pumping. The surface diversion amount accounts for stream inflows and outflows, and for canal imports and exports, for each Subregion, and is detailed in Table 3.6A-D, "Streams and Diversions by Subregion". The pumped amount is based on USGS records for 1961-77, which in turn where based on power records. For years outside the USGS study, data was extrapolated based on CUAW and annual surface water diversions.

The report did not directly supply efficiency data; a regional efficiency value was computed. From Table 3.4J, "Water Budget for Region 10 (DSA 49A)", for the year 1980 only, the CUAW for agricultural use was 715.2 TAF, and the irrigation supply was 1935.4 TAF. This yields a regional efficiency of 37%. An efficiency value this low is unreasonable, given the other data reviewed in this report--it doesn't make sense. Perhaps something is missing, incorrect, or misunderstood.

Boyle Engineering Company. 1986.

Title: Evaluation of On-Farm Agricultural Management Alternatives.

Data: All data is from Table 6.6, "Estimated Irrigation Efficiencies for Principal Crops Grown in the San Joaquin Valley", p. 6-44.

The area of study which encompasses the Grasslands study area is the "Valley Westside" region, which according to the table footnote is the Delta Mendota service area.

The efficiency numerator (irrigation water beneficially used) was estimated as the crop evapotranspiration (unstressed) less rainfall which occurred during the growing season (where off-season rainfall was assumed to be ineffective). Crop ET data came from DWR's Bulletin 113-3, dated 1975.

The efficiency denominator (irrigation water applied) was applied water, also derived from DWR's Bulletin 113-3.

The on-farm efficiencies were given as part of the table (the "last" column, after crop ET, rain, etc.). Table 6.6 gives efficiencies by crop, for fifteen crop and crop categories typical of the region. Only the more common crops are listed in the tabular summary given in this report.

Roos, Maurice. 1990.

Title: Bay-Delta Estuary Proceedings.

Data: The area of study which encompasses our study area is DAU 216. Our study area is in the south end of DAU 216.

For this study, the SAE (average field seasonal application efficiency) is defined as (ETAW + LR + CP) / AW, where ETAW is the ET of applied water, LR is assumed to be 5 %, CP refers to nonconsumptive cultural practices, and AW is applied water use. The calculation of ETAW also depends on estimated irrigated acreage and cropping patterns. ETAW accounts for some under-irrigation typical of the area. It isn't clear from the notes which year or time period was under consideration.

The SAE for DAU 216 is 70% (Subworkgroup #1, Summary of Findings, Final Draft, November 2, 1990).

Los Banos Resource Conservation District Mobile Lab. 1988.

Title: Technical Report to the San Joaquin Valley drainage program on the Los Banos Resource Conservation District.

Data: The area of study was not specified, except to say the "Target Area" included the Merced, Fresno, and Kings counties. The study included 31 irrigation evaluations, which were done during the summer season in 1988.

DU's (distribution uniformities) were measured for a single event, which occurred late in the crop's growing season. DU calculations were based on single furrow measurements and "Waterman A" program calculations. The mean DU for the study was 86%, a high value due to (1) the timing of the evaluations (in the summer when intake rates are low), and (2) due to the fact that the measurements ignore many other components of a field DU.

DU information was not included in the determination of efficiencies. The formula for efficiency was (irrigation water beneficially used * 100%) / (gross irrigation water applied). Crop beneficial use was determined by "crop ET plus leaching factors". Irrigation water beneficially used was crop beneficial use less effective precipitation. How effective precipitation was determined was not specified. How leaching requirements were included in crop beneficial use was not specified, either.

The mean annual efficiency for all 31 fields was 75%, with a range of 48 to 95%. Annual efficiencies by system and crop were also given.

Burt, Charles M. and K. Katen. 1988.

Title: Westside Resource Conservation District 1986/87 Water Conservation and Drainage Reduction Program.

Data: The scope of the study was the Westside RCD, an area roughly equivalent to Westlands Water

District, though slightly larger.

A total of 83 fields representing approximately 11,000 acres were evaluated. Evaluations consisted on a pre-season field evaluation, a mid-season field evaluation, and an assessment of all remaining irrigations based on field inflows, etc. The efficiency was defined as the percentage of irrigation water beneficially used relative to gross irrigation water applied.

The weighted mean of all efficiencies was 66%, with a range of 33% to nearly 100% (for under-irrigated fields). Efficiencies were also given by crop and irrigation system type.

Ayars, James E. and G. Schrale. 1990.

Title: Irrigation Efficiency and Regional Subsurface Drain Flow on the West Side of the San Joaquin Valley.

Data: The area of study is the Panoche Water District. The area of study is part of and wholly inside the Grasslands study area.

The efficiency for the study was defined as (ET - R + Lr) / I, where ET is the evapotranspiration of the crop, R is effective rainfall, Lr is the leaching requirement, I is the irrigation amount. District records for irrigation deliveries, cropping patterns and acreage, and precipitation were used, along with Westlands Water District Water Conservation and Management Handbook (1985) values for potential crop ET. Off-season evaporation on fallow fields was also assessed.

The study included two approaches to determining efficiencies. For all district irrigated acreage, grouped land units were used due to the difficulty of determining field deliveries. Additionally, single field studies were done at six sites.

For the grouped land unit study, the overall efficiency for the district for 1987 was 72%, with a range of 29% to 141%. By crop, efficiencies were 87% for cotton, 52% for tomato, and 103% for alfalfa. The high value for cotton was partly attributable to the low permeability of the soils on which cotton was grown, and shallow groundwater contributions. The low efficiency value for tomatoes was partly attributable to higher permeability of soils on which tomatoes were grown. The very high efficiency for alfalfa was partly attributable to the fact growers do not irrigate their alfalfa fields year round, so the ETAW would be unrealistically high, and also alfalfa could have been using shallow groundwater. The overall efficiency for the district for 1988 was 78%.

For the single field studies, single furrow DU (distribution uniformity) and AE (application efficiency) values were determined for the pre, the first, and the last irrigations. No seasonal efficiency value was given. In general, the DU values were high, except for one pre-irrigation on cotton. The AE values varied considerably, with a low of 32% and a high of 171%, when calculated without runoff.

Westlands Water District. 1989.

Title: Water Conservation and Drainage Reduction Programs 1987-88.

Data: The scope of the study was WWD; the northern boundary of the district is just south of the Grasslands study area.

The report uses the term AIE (annual irrigation efficiency) for efficiency, where AIE is the percentage of the sum of water used to replace moisture deficiencies in the plant root zone, water used beneficially for cultural practices, and water used for the annual leaching requirement, relative to the gross irrigation amount. Minor losses due to evaporation and conveyance losses are estimated and included in the calculations.

The AIE for all fields was 71%. By system, furrow systems averaged 69%, sprinkler/furrow systems (where sprinklers were used for the pre or first irrigation) averaged 75%, sprinkler averaged 72%, and Drip averaged 77%. By crop, cotton averaged 69%, tomatoes averaged 75%, and all other crops averaged 69%.

Soil Conservation Service. 1990.

Title: Irrigation Evaluations in the Grasslands Area.

Data: 57 fields were evaluated, with report dates spanning from February, 1987 to August, 1990.

The methodology for efficiency determination followed that of the mobile labs in general; see comments on the report by the Los Banos RCD Mobile Lab, 1988.

Of the 57 fields evaluated, 51 were furrow systems. The average annual efficiency was 70%, with a range of 37 to 100%.

California Department of Water Resources, USDA Soil Conservation Service, Shafter - Wasco RCD and Pond - Poso RCD. 1978.

Title: Irrigation Water Management in the Southern San Joaquin Valley, 1977.

Data: 7 fields were evaluated in the vicinity of Shafter and Wasco during 1977. There were 4 furrow systems and 3 border strip irrigation systems. Crops grown were cotton, almonds, barley, and alfalfa.

The field efficiency was called Ea (water application efficiency) and defined as (Wet + We - Re)/ Wi * 100%, where Wet was crop unstressed ET, We was the leaching requirement, Re was effective rainfall, and Wi was water delivered to the field. Crop monthly crop coefficients used in estimating crop unstressed ET were taken from DWR's Bulletin 113-3 (1974). The reference ET was taken from local weather stations with evaporation pans. The rainfall was estimated for each field using data from four local weather stations.

The average seasonal efficiency was 77%, with a range of 53 to 100%.

California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1980.

Title: Irrigation Water Management in the Southern San Joaquin Valley, 1978.

Data: 8 fields were evaluated in the vicinity of Shafter, Wasco and Buttonwillow. There were 5 furrow systems and 3 border strip systems. Crops were cotton, alfalfa, almonds, barley and soybeans.

The efficiency was determined as in the previous study (1977) in this series by DWR, with the exception that off-season evaporation from fallow ground was accounted for.

The average annual efficiency was 63%, with a range of 31 to 100%.

California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1981.

Title: Irrigation Water Management in the Southern San Joaquin Valley, 1979.

Data: 9 fields were evaluated in the vicinity of Shafter, Wasco and Buttonwillow. There were 6 furrow systems and 3 border strip systems. Crops were cotton, alfalfa, almonds, barley and soybeans.

The efficiency was determined as in the previous (1978) study in this series by DWR, with the exception that leaching requirements were not included.

The average annual efficiency was 77%, with a range of 44 to 100%.

California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1984.

Title: Irrigation Water management in the Southern San Joaquin Valley, 1980.

Data: 13 fields were evaluated in the vicinity of Shafter, Wasco and Buttonwillow. There were 9 furrow systems and 4 border strip systems. Crops were cotton, alfalfa, almonds, barley and grain sorghum.

The efficiency was determined as in the previous (1979) study in this series by DWR.

The average annual efficiency was 70%, with a range of 44 to 100%.

California Department of Water Resources, USDA Soil Conservation Service and Pond - Shafter - Wasco RCD. 1985.

Title: Irrigation Water management in the Southern San Joaquin Valley, 1981.

Data: 11 fields were evaluated in the vicinity of Shafter, Wasco and Buttonwillow. There were 7 furrow systems and 4 border strip systems. Crops were cotton, alfalfa, almonds, and barley.

The efficiency was determined as in the previous (1980) study in this series by DWR.

The average annual efficiency was 75%, with a range of 56 to 100%.

California Department of Water Resources, USDA Soil Conservation Service and Pond - Shafter - Wasco RCD. 1988.

Title: Irrigation Water management in the Southern San Joaquin Valley, 1983.

Data: 10 fields were evaluated in the vicinity of Shafter, Wasco and Buttonwillow. There were 6 furrow systems and 4 border strip systems. Crops were cotton, almonds, wheat, and grain sorghum.

The efficiency was determined as in the previous (1981) study in this series by DWR.

The average annual efficiency was 72%, with a range of 34 to 100%.

CONCLUSION

It is apparent from this literature review that there is virtually no correlation between efficiency values and methodologies. For example, it is theoretically correct that lower efficiency values result when beneficial use terms such as leaching requirements are ignored, but no such trend is noted in the data.

Differences in efficiency equations are one reason for the observed discrepancies. Problems associated with determination of water destinations, of which the efficiency equations are comprised, are another reason. Finally, the interaction of all parameters that affect efficiency make direct comparisons difficult.

The definition of efficiency, termed IE, utilized in this report, provides a comprehensive measure of efficiency. In addition to the equation, however, appropriate methodologies need to be designed so that the terms of the equation can be ascertained with reasonable certainty.

BIBLIOGRAPHY

Ayars, James E. and G. Schrale. 1990. Irrigation efficiency and regional subsurface drain flow on the west side of the San Joaquin Valley. Submitted to California Department of Water Resources. 120 p.

Boyle Engineering Corporation. 1986. Evaluation of on-farm agricultural management alternatives. Prepared for the San Joaquin Valley Drainage Program under US Bureau of Reclamation contract. 100 p. (approx.).

Broadview Water District. 1982. San Luis drain plan of study - drainage inquiry. 2 p.

Broadview Water District. 1984. Information needs from westside water districts. Submitted to Regional Water Quality Control Board, Central Valley Region.

Broadview Water District. 1989. Drainage Operation Plan. Submitted to California Regional Water Quality Control Board, Central Valley Region. 50 p. (approx.).

Burt, Charles M. and K. Katen. 1988. Westside resource conservation district 1986/87 water conservation and drainage reduction program. Technical report to the Office of Water Conservation, California Department of Water Resources. 29 p.

California Department of Water Resources, USDA Soil Conservation Service and Pond - Shafter - Wasco RCD. 1988. Irrigation Water management in the Southern San Joaquin Valley - 1983. 69 p.

California Department of Water Resources. 1983. Field irrigation deliveries in the San Joaquin Valley - a sampling of amounts of irrigation water applied to agricultural crops. 74 p.

California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1980. Irrigation water management in the Southern San Joaquin Valley - 1978. 45 p.

California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1984. Irrigation Water management in the Southern San Joaquin Valley - 1980. 91 p.

California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD and Pond - Poso RCD. 1981. Irrigation Water management in the Southern San Joaquin Valley - 1979. 64 p.

California Department of Water Resources and UC Cooperative Extension. 1983. Crop water use - a guide for scheduling irrigations in the southern San Joaquin Valley, appendix c. 7 p.

California Department of Water Resources, USDA Soil Conservation Service, Shafter - Wasco RCD and Pond - Poso RCD. 1978. Irrigation Water management in the Southern San Joaquin Valley - 1977. 45 p.

California Department of Water Resources, USDA Soil Conservation Service and Pond - Shafter - Wasco RCD. 1985. Irrigation Water management in the Southern San Joaquin Valley - 1981. 71 p.

California Department of Water Resources. 1975. Vegetative water use in California, 1974 - Bulletin 113-3. 104 p.

Central California Irrigation District. 1990d. Information report, required by the agricultural water management planning act. 7 p.

Central California Irrigation District. 1985. Water supply sources. 5 p.

Central Valley Water Use Study Committee. 1987. Irrigation water use in the Central Valley of California.

Central California Irrigation District. 1984. 1983 shallow groundwater third annual report. 3 p.

Central California Irrigation District. 1990c. Manager telephone interview. 1 p.

Central California Irrigation District. 1990. Drainage operation plan, required by Regional Water Quality Control Board, Central Valley Region. 6 p.

Central California Irrigation District. 1990b. Crop reports. 7 p.

CH2M Hill. 1988. On-farm irrigation system hydrological characterizations for mathematical modeling (draft). For San Joaquin Valley Drainage Program. 50 p.

CH2M Hill. 1988b. San joaquin valley hydrologic and salt load budgets. 43 p.

CH2M Hill. 1989. Irrigation system costs and performance in the San Joaquin Valley. For the San Joaquin Valley Drainage Program.

Charleston Drainage District. 1990. Drainage operation plan. Required by Regional Water Quality Control Board, Central Valley Region. 7 p.

Department of Water Resources, San Joaquin District. 1981. Hydrologic data - surface water flow, diversions, surface water quality - 1980 water year.

Dinar, A., J.D. Rhoades, P. Nash and B.L. Waggoner. 1990. Production functions relating crop yield, water quality and quantity, soil salinity and drainage volume. Draft. 31 p.

Dinar, A., S.A. Hatchett and E.T. Loehman. 1990. Regional analysis of regulations and incentives for drainage quality and quantity control. 13 p.

Dinar, A. and M.B. Campbell. 1990. Adoption of improved irrigation and drainage reduction technologies in the westside of the San Joaquin Valley part I: literature review, survey methods and descriptive farm-level results (draft). For the San Joaquin Valley Drainage Program. 180 p. (approx.).

Firebaugh Canal Water District. 1990b. Informational report. Required by The Agricultural Water Management Planning Act. 7 p.

Firebaugh Canal Water District. 1990. Drainage operation plan. Submitted to the Regional Water Quality Control Board, Central Valley Region. 2 p.

Firebaugh Canal Company. 1985. Information Needs from Westside Water Districts. Submitted to Regional Water Quality Control Board, Central Valley Region. 2 p.

Hanson, B.R. 1989. A systems approach to drainage reduction in the San Joaquin Valley. Agricultural Water Management, 16:97-108.

Hoffman, G.J. and G. Schrale. 1988. Management strategies to reduce drainage from irrigated agriculture.

Presented at ASAE Winter Meeting, Chicago, Ill, Dec 13-16. 14 p.

Hoffman, G.J., D.W. Meek and J.L. Gartung. 1988. Impact of improved irrigation on subsurface drainage. Presented at ASAE Winter Meeting, Chicago, IL, Dec 13-16.

J.M. Lord, Inc. 1988. Phase II report - innovative techniques to reduce subsurface drainage flows. Prepared under contract for the San Joaquin Valley Drainage Program, Mar.

J.M. Lord, Inc. 1987. Phase I report - innovative techniques to reduce subsurface drainage flows. Prepared under contract for the San Joaquin Valley Drainage Program, Nov.

J.M. Lord, Inc. 1989. Phase III report - innovative techniques to reduce subsurface drainage flows. Prepared under contract for the San Joaquin Valley Drainage Program, Oct.

J.M. Montgomery Consulting Engineers Inc. and Boyle Engineering. 1990. Central valley ground-surface water model. 400 p. (approx.).

Los Banos Resource Conservation District Mobile Lab. 1988. Technical report to san joaquin valley drainage program on the los banos resource conservation district. 14 p.

Pacheco Water District. 1985. Well water analysis. Submitted to Water Quality Control Board, Central Valley Region. 4 p.

Pacheco Water District. 1982. San Luis drain plan of study - drainage inquiry. Submitted to Regional Water Quality Control Board, Central Valley Region. 1 p.

Pacheco Water District. 1984. Information needs from westside water districts. Submitted to Regional Water Quality Control Board, Central Valley Region. 4 p.

Pacheco Water District. 1990. Drainage operation plan. Submitted to Regional Water Quality Control Board, Central Valley Region. 8 p.

Panoche Water District. 1986. Estimated drainage outflow from panoche drainage district. Submitted to Water Quality Control Board, Central Valley Region. 3 p.

Panoche Water District. 1985. Report on the extent of drainage water discharges from areas within panoche drainage district. Submitted to Water Quality Control Board, Central Valley Region. 3 p.

Panoche Drainage District. 1989. Drainage operation plan. Submitted to Regional Water Quality Control Board, Central Valley Region. 13 p.

Panoche Water District. 1982. San Luis drain plan of study - drainage inquiry. Submitted to Regional Water Quality Control Board, Central Valley Region. 2 p.

Roos, Maurice. 1990. Minutes of the Bay-Delta Estuary Proceedings -Agricultural Water Conservation Sub-Work Groups 1, 2, & 3. 100 p. (approx.).

San Joaquin Valley Drainage Program. 1990. A management plan for agricultural subsurface drainage and related problems on the Westside San Joaquin Valley - final report of the San Joaquin Valley drainage program. 183 p.

San Joaquin Valley Drainage Program. 1987. Developing options - an overview to solve agricultural drainage and drainage-related problems in the San Joaquin Valley. 28 p.

Soil Conservation Service. 1990. Irrigation Evaluations in the Grasslands Area. Copies of evaluation reports were given to this study, but with field owner identification withheld.

U.S. Geological Survey. 1989. Preliminary assessment of sources, distribution, and mobility of selenium in the san Joaquin Valley, California. Water-Resources Investigations Report 88-4186. 129 p.

Westlands Water District. 1990. Crop coefficient information request. Transmittal in response to inquiry concerning WWD's crop coefficients in their northern area. 21 p.

Westlands Water District. 1989. Water conservation and drainage reduction programs 1987-88. 55 p.

Wichelns, D., D. Nelson and T. Weaver. 1988. Farm-level analysis of irrigated crop production in areas with salinity and drainage problems. Report to the San Joaquin Valley Drainage Program. 78 p.

Wichelns, D. 1988. A farm-level model of irrigation and drainage management in drainage problem areas. Report to the San Joaquin Valley Drainage Program. 41 p.

Wichelns, D., R.E. Howitt and G.L. Horner. 1988. The economic effects of salinity and drainage problems. California Agriculture, January February 1988, pp. 10-13.

Wichelns, D. and J.D. Oster. 1991. Irrigation uniformity and cotton yields in the San Joaquin Valley. California Agriculture. Vol 45 No. 1, pp. 13-15.

ABBREVIATED COMMENTS REGARDING BACKGROUND LITERATURE

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MAPS OF DISTRICT BOUNDARIES

(Boyle Engineering Corporation, 1986).

- Figure 3.3, pp 3-12, Map of San Joaquin Valley DAU's (detailed analysis units). Shows county lines in addition to DAU boundaries.

(Broadview Water District, 1989)

- Location map of Broadview WD, relative to state and relative to surrounding counties.
- Broadview WD, with section lines and numbers.
- Broadview WD, with field numbers.

(California Department of Water Resources, 1983)

- Figure 2, "Detailed Analysis Units in the San Joaquin Valley", p. 21. Best map of DAU's.

(Charleston Drainage District, 1990)

- Charleston DD, with section lines, canals, pipelines, drainage ditches, etc.

(Firebaugh Canal Water District, 1990b)

- Map of district boundaries.

(Panoche Drainage District. 1989)

- Map with Panoche Drainage District boundary. Shows the various enclosed water district boundaries also.

MAPS OF SOIL SERIES

(J.M. Lord, Inc., 1987)

- Figure 3, "Soils Map", p. 11. Significant, since study area is nearly identical to our study area.

ET FOR SPECIFIC CROPS, BY YEAR

(Boyle Engineering Corporation, 1986).

- Table 3.7, pp 3-20, Table of DAU's vs major water agencies.
- Table 3.8, pp 3-21, Table of DAU's vs Applied water and ET of applied water for 1980. Adapted from DWR Bulletin 214, 1982.

(Broadview Water District, 1989)

- Evapotranspiration data, in 3-d bar graphs, showing CIMIS weather station #7 for crop years (Oct-Sep) 1986-89. Essentially useless. First graph shows ET by month, in inches, with resolution of 1 inch. Second graph shows cumulative ET by month.

(California Department of Water Resources, USDA Soil Conservation Service, Pond - Shafter - Wasco RCD, 1988)

- Estimated growing season ET, effective precipitation, and ET of applied irrigation water, table 5. For ten fields included in study. See pp 15.

(California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD, Pond - Poso RCD, 1984)

- Estimated growing season ET, effective precipitation, and ET of applied irrigation water, table 6. For thirteen fields included in study. See pp 17.

(California Department of Water Resources, 1983)

- Table 1, "Estimated Evapotranspiration of Applied Water For Provincial Crops - San Joaquin Valley", p. 13. Taken from DWR Bulletin 113-3.

(California Department of Water Resources, UC Cooperative Extension, 1983)

- Monthly ET as a percent of "normal" for 1982, at USDA Cotton Station and at DWR's Bakersfield 10NW agro-climatic station.
- Monthly ET as a percent of "normal" for 1982, at DWR's Fresno State agro-climatic station and at DWR's Bakersfield 10 NW agro-climatic station.
- Table of estimated crop water use (missing, since pages 5, 6 in report are missing).
- Calculated ET-Alfalfa for Southern San Joaquin Valley, 1982.

(California Department of Water Resources, USDA Soil Conservation Service, Shafter - Wasco RCD, Pond - Poso RCD, 1981)

- Estimated growing season ET, effective precipitation, and ET of applied irrigation water, table 5. For nine fields included in study. See pp 13.

(California Department of Water Resources, USDA Soil Conservation Service, Buena Vista RCD, Shafter - Wasco RCD, Pond - Poso RCD, 1980)

- Estimated growing season ET, effective precipitation, and ET of applied irrigation water, table 5. ET estimated from pan evaporation data, and crop kc data developed from DWR bulletin 113-3, table 5. For seven fields included in study. See pp 13.

(California Department of Water Resources, USDA Soil Conservation Service, Shafter - Wasco RCD, Pond - Poso RCD, 1978)

- Estimated growing season ET, effective precipitation, and ET of applied irrigation water, table 4. See pp 11.
- Explanation: for six fields included in investigation. ETp estimated from evaporation data from DWR's Wasco 8SW agro-climatic station. Crop Kc taken from DWR bulletin 113-3, Table 5. See pp 4.

(California Department of Water Resources, 1975)
- ETpan, and crop Kc based on ETpan.

(Central Valley Water Use Study Committee, 1987)
- Excellent discussion and maps of Hydraulic Study Areas (HSA's), Planning Subareas (PSA's), and Detailed Analysis Units (DAU's). See pp 3-8.
- Crop ET estimates based on DWR bulletin 160-83, which in turn used DWR bulletin 113-3. Only basin wide ET usage was reported. See Table 1, "Evaporation of Water Applied to Agricultural Crops in the Central Valley (Excluding the Sacramento-San Joaquin Delta)", p. 10. Shows irrigated area and ETAW for SJV HSA's. See Table 5, "Irrigated Area and Evapotranspiration of Water Applied to Agricultural Crops of Saline Sink Area", p. 20. Shows irrigated area and ETAW for SJV DAU's.

(CH2M Hill, 1989)
- Consumptive use for crop categories, pp 24. Based on DWR 133-4, pp 21. Very general. Crop categories were alfalfa and other hay crops, trees and vines, row crops (primarily cotton), grains, vegetable crops, grasslands (based on grains), wetlands (rice).

(CH2M Hill. 1988)
- Table 5, "Mean Values of Beneficial Water Use by Crop". Shows crop (with sample size), and pre-season, mid-season, and rainfall. Data taken from WWD, 1986-87.

ET for specific crops, by year

(Hoffman, G.J., D.W. Meek and J.L. Gartung, 1988)
- Research and "current recommendations" ET values for cotton on west side of San Joaquin Valley, 1987. pp 7, 21. Not clear where the data came from, as specific reference wasn't given. Graph only, no tabular data.

(J.M. Lord, Inc., 1989)
- ETp, ET*kc, and Crop ET, for three fields. See pp 1-4 for information on fields. See fig. 14, 28, 41 for curves. Graph only, no tabular data.

(J.M. Lord, Inc., 1987)
- ET and Cotton Kc curve for 1987, using Telles CIMIS weather station for ETp, and J.M. Lord Cotton Kc curve. Graph only, no tabular data.

(Los Banos RCD, 1988)
- Annual Beneficial Use, by crop, for 31 fields investigated by the Mobile Lab. No indication on how values were determined.

(Westlands Water District, 1990)
- Normal year ET data, for northern part of WWD (Tranquillity).
- "Well watered" crop coefficients, for alfalfa, almonds, barley, cotton, melons, sugar beets, safflower, and tomatoes.

WATER DELIVERIES TO SPECIFIC CROPS

(Broadview Water District, 1989)

- Graph of applied water (ft), by crop, for 1986-88. For Cotton, Tomatoes, Melons, Wheat, Sugar beets, and Alfalfa seed. Same information is in table 1, pp 4, in supplement entitled "An Increasing Block-Rate Pricing Program To Motivate Water Conservation and Reduce Subsurface Drain Water", parts of a paper by D. Wichelns and D. Cone (manager). No discussion.
- Tables entitled "Field-specific irrigation depths and descriptive notes for cotton fields, Broadview water district, 1989", etc. for cotton, tomato, wheat, and melon fields. From paper "An Increasing Block-Rate Pricing Program To Motivate Water Conservation and Reduce Subsurface Drain Water." Contains pre-plant and mid-season irrigation amounts (ft) for fields in the district.

(California Department of Water Resources, 1983)

- Table 11, "Average Field Irrigation Deliveries - San Joaquin Basin - DAU 216", p. 50. For crops included in study, shows irrigation method, total number and area of fields, field deliveries (ft) by month and season, and other less important items. Our study area resides in the southern end of DAU 216.

(Hoffman, G.J., D.W. Meek and J.L. Gartung, 1988)

- Table 2, "Water applied during pre-plant irrigation for several crops in different irrigation districts", p. 13. Shows year (84-85, 85-86, or 86-87), crop (cotton, cantaloup, corn, beans), crop area (ha), and irrigation amount (mm). Typically 300 mm, or 1 ft.
- Table 3, "Water applied as pre-plant irrigations for cotton in the Westlands Water District for several years", p. 13. Shows year (82-83, 83-84, 84-85), crop area (ha), rainfall (mm), and irrigation amount (mm), for both inside the 17,000 ha drainage area and outside (upslope). For 82-83 and 83-84, the average irrigation amount was typically 310 mm, even though 82-83 received substantial winter rainfall. For 86-87, the average irrigation amount was 210 mm.

(J.M. Lord, Inc. 1989)

- Same as for (J.M. Lord, Inc. 1988), except for the following year, and that irrigation evaluations appeared to be of higher quality.

(J.M. Lord, Inc. 1988)

- See Chapter III, Results, for irrigation evaluations on 3 study fields. These fields were under JM Lord supervision, so irrigation practices were improved somewhat based on first irrigation or first set evaluations. Only single furrow evaluations were used to determine the DU's. Gives tile and deep drain flows and chemical analyses for season.

(Los Banos Resource Conservation District Mobile Lab. 1988)

- Table 1, "Annual Summary by Irrigation Method", p. 10. Shows (for 31 fields studied in target area within Merced, Fresno, and Kings counties) for 4 typical irrigation systems, the IE, DU (single event mid to late season), and water destinations.

(Wichelns, D., 1988)

- Table 2, "Average Water Application Rates in the Broadview Water District, by Crop, 1986 through 1988" (ft), p. 9.
- Table 3, "Field-Specific Irrigation Events for Cotton in the Broadview Water District, 1988" (ft), p. 10. For 24 cotton fields in BWD, shows acreage, irrigation application amount for each irrigation event, and total water applied.
- Table 8, "Cotton Irrigation Quantities, Broadview Water District, 1987", p. 22. Shows range of observed values for pre, mid and total irrigation applied water (ft), for 22 of 28 cotton fields.

(Wichelns, D., D. Nelson and T. Weaver, 1988)

- Table 7, "Actual and Estimated Water Application Rates for Selected Crops in the Broadview Water District, 1983-86", p. 49. Shows for crops barley, cotton, sugar beets, wheat, melons, tomatoes, alfalfa seed, alfalfa hay, corn, dry beans, and others, the actual application (ft) for 1985, 86, and estimated application average for 1983-86.

WATER DELIVERIES TO REGION

(Boyle Engineering Corporation, 1986)

- Table 3.5, "Net Water Supply in San Joaquin and Tulare Lake Hydrologic Study Areas - 1980", pp 3-17. Shows surface supply and groundwater supply (TAF), with several basic breakdowns (Surface, CVP, etc.). Based on DWR bulletin 160-83, 1983.
- Table 3.6, "Hydrologic Balance for the San Joaquin and Tulare Lake Hydrologic Study Areas - 1980", pp 3-18. Shows net water supply and net water use (TAF) with breakdowns.

(Central California Irrigation District, 1990c)

- Riparian rights, 532 TAF per calendar year, exchange contract with USBR.
- Sell 470 TAF USBR water delivered to fields, metered. Loose to seepage, evap, and spills, 532 less 470, or 62 TAF.

(Department of Water Resources, San Joaquin District, 1981)

- Table A-4, "Diversion - San Joaquin River and Mendota Pool - October 1979 through September 1980", p. 78. Deliveries to water users (AF) by month, and for water year.
- Table A-6, "Deliveries From Central Valley Project Canals - October 1979 through September 1980", p. 80. Deliveries to water users (AF) by month, for Delta-Mendota Canal, Madera Canal, and Millerton Lake.
- Table A-7, "Deliveries from California Aqueduct - October 1, 1979 through September 30, 1980", p. 82. Deliveries to water users (AF) by month, for federal customers and state contractors.

(Dinar, A. and M.B. Campbell, 1990)

- Water deliveries (surface water) by region discussed on pp 30, and summarized in Table 10, pp 64. Total breakdown of water sources summarized in Table 13, pp 67.
- "region" means areas delineated by SJVDP, and discussed pp 13 and Table 1, pp 55. They are very large--our region is the Grasslands subarea (321,000 acres).

WATER DELIVERIES TO DISTRICTS

(Ayars, J.E. and G. Schrale. 1990)

- Table 14, "Water Balance summary for Panoche Water and Drainage District (includes Oro Loma, Eagle Field, and Mercy Springs Water Districts)", p. 91. For 1987-88 water years. Shows water delivery, water use, RO+DF (calculated), and RO+DF (measured).

(Broadview Water District, 1989)

- Table of water deliveries by month, for water years 1980-89 (Mar-Feb), and table of water deliveries per acre, for water years 1980-89. Assume this is D-M canal water.

  - Graph of water deliveries (D-M canal) and field deliveries, for water years 1980-88. Not clear what is meant by field deliveries, and why they are for some years substantially higher; i.e. no discussion.
- Table of water deliveries by year, for crop years 1980-89 (Oct-Sep), and crop acreage, and delivered per acre.

(Broadview Water District, 1984)

- Table of annual average inflow to district from D-M canal (AF), by month, for 1984.
- Table of average inflow of surface drainage water (ag tail water only) (AF), by month, for 1984.

(Central California Irrigation District, 1990)

- Water supply is (on average) 532 TAF per 143,000 A in a normal year, and 424 TAF in a critical year. Pump an average of 20 TAF per year.

(Central California Irrigation District, 1990d)

- D-M canal deliveries to CCID, by year 1987-89. (Always 532 TAF).

(Central California Irrigation District, 1985)

- Surface water annual average, by year (500 TAF), and by month.

(Central California Irrigation District, 1984)

- Deliveries and water conveyance losses (AF), by year 1974-83, and average water delivery per acre (AF/A), assuming 153,600 irrigated acres.

(Department of Water Resources, San Joaquin District, 1981)

- Table A-4, "Diversion - San Joaquin River and Mendota Pool - October 1979 through September 1980", p. 78. Deliveries to water users (AF) by month, and for water year.
- Table A-6, "Deliveries From Central Valley Project Canals - October 1979 through September 1980", p. 80. Deliveries to water users (AF) by month, for Delta-Mendota Canal, Madera Canal, and Millerton Lake.
- Table A-7, "Deliveries from California Aqueduct - October 1, 1979 through September 30, 1980", p. 82. Deliveries to water users (AF) by month, for federal customers and state contractors.

(Firebaugh Canal Water District, 1990)

- Surface water supply is 85,000 AF.

(Firebaugh Canal Water District, 1990b)

- Table 1, "Water Supply", p. 5. Shows annual exchange water diversions (AF) for years 1986-88.

(Firebaugh Canal Company, 1985)

- Average annual inflow (80,000 AF) and monthly inflows, Jan through Nov (AF). Indicates "all surface water".

(Pacheco Water District. 1990)

- No mention of deliveries, but sources are Outside Canal, Delta-Mendota Canal, and the San Luis Canal. p. 2.

(Pacheco Water District. 1984)

- Water deliveries, 1300 AF per year. Sources are San Luis Canal, Delta-Mendota Canal, and CCID Outside Canal.
- Surface drainage water inflow, 2000 AF per year.

GROUNDWATER USAGE

(Boyle Engineering Corporation, 1986)

- Table 3.5, "Net Water Supply in San Joaquin and Tulare Lake Hydrologic Study Areas - 1980", pp 3-17. Shows surface supply and groundwater supply (TAF), with several basic breakdowns (Surface, CVP, etc.). Based on DWR bulletin 160-83, 1983.

(Central California Irrigation District, 1990d)

- Table of groundwater pumped from 41 district wells, by year 1987-89. CCID had no information on farmers wells and pumping.

(Central California Irrigation District, 1985)

- Deep well annual average (11,730 AF), and by month.

(Firebaugh Canal Water District, 1990b)

- There are 10 district wells, but water quality is poor, hence they are rarely used. There are no private wells in the district.

CROP ACREAGE BY DISTRICT

(Ayars, J.E. and G. Schrale. 1990)

- Table 2, "Approximate total acres of crops harvested in 1987 and 1988 in the Panoche Water District", p. 15. Note wide variety of crops (20 different crops were grown) and note total acreages of 32878 and 31316 A. Roughly 47% was cotton, 16% was alfalfa (for hay?) and tomatoes (canning?), and the rest 5% or less.

(Broadview Water District, 1989)

- Table of crop acreage for 1980-89 water years, for cotton, melons, alfalfa for seed, wheat, canning tomatoes, sugar beets, lima beans, barley, alfalfa for hay, other (with notes), and fallow (with notes). Preliminary acreages only for 1989.

(Central California Irrigation District, 1990b)

- Crop acreages for 1985-89, and estimate for 1990.

(Central California Irrigation District, 1990c)

- 143,000 gross irrigated acres. Less 6% for roads, houses, then 134,400 acres. Double and triple cropping result in larger crop acreages.

(Central California Irrigation District, 1990d)

- 143,000 A in CCID. The exchange contract allows 159,000 gross acres. CCID has received requests for more than 16,000 A to be included. p 1.
- 134,500 irrigable acres in CCID. p 2.
- Table 2, Cropping pattern (A), by year 1987-89. p 7.

(Firebaugh Canal Water District, 1990b)

- Total acreage is 22,400 acres. p. 1.
- Irrigable acreage is 21,700 acres. p. 2.
- Table 2, "Cropping Pattern", p. 6. Shows crops (alfalfa, sugar beets, cotton, cover, grain, menos, rice, vegetables, apples), and acreage for years 1986-88.

(J.M. Lord, Inc., 1987)

- Table 1, "Percentages of Major Crops in the Drainage Area, 1978-84", p. 8. Significant, since area of study is nearly identical to our area of study. For crops (cotton, grains, alfalfa, sugar beets, tomatoes, melons, safflower, other vegetables), shows % of area. In sum 48% cotton, 13% grains, 8% tomatoes, all others below 5%.

FIELD SIZE BY DISTRICT

(Broadview Water District, 1989)

IRRIGATION SYSTEM ACREAGE BY DISTRICT

(Ayars, J.E. and G. Schrale. 1990)

- Table 1, "Irrigation systems inventory for the Panoche Water and Drainage District", p. 14. Shows acreages for 4 major system types: high pressure sprinkler (2122 A), furrow irrigated from gated pipeline (3230 A), gravity irrigation from adjacent canal (32332 A), gravity with surge flow (30 A).

IRRIGATION PRACTICES IN THE AREA

(Ayars, J.E. and G. Schrale. 1990)

- Tailwater mgt done in 4 ways (p. 14): (1) unreturned discharge into open drains, (2) recycled within the field of origin, (3) Recycled in downstream fields under same management, (4) unreturned discharge to open drains by management "A", and recovery by pumping by downstream user (management "B").
- p. 17. Not possible to determine the precise amount of water infiltrated onto a given field, since (1) district delivery points are upstream of several field delivery points, (2) a field's tailwater may be recycled onto the same field, onto another field belonging to same owner, or onto another field considerably removed and belonging to different owner, but along the surface drainage courseway.

(Boyle Engineering Corporation, 1986)

- Table 4.4, "Summary of Irrigation Methods Commonly Used for Field Crop Production", pp 4-5. Shows brief table of major field crops (small grain, rice, cotton, safflower, sugar beet, field corn, grain sorghum, beans, alfalfa seed) and irrigation methods.
- Table 4.5, "Summary of Irrigation methods Commonly Used for Truck Crop Production", pp 4-6. Shows brief table of major field crops (tomato, onion, garlic, potato, melon, other vegetables) and their irrigation methods.

(CH2M Hill. 1989)

- See pp. 1-11 for irrigation system background info and performance characteristics.

(CH2M Hill. 1988)

- Discussion on extrapolating WWD management practices to other districts or other environments. Interesting in that it attempts to predict management trends based on increasing water cost, increasing water availability relative to acreage, rising water table into root zone, decreasing district distribution flexibility, increasing field size, and varying district regulations.
- See appendix D, "Overview of Irrigation Methods and Systems". Discussion of furrow, tailwater re-use, level furrow, furrow length, surge flow, border strip, hand move, permanent set, and drip.

(Firebaugh Canal Water District, 1990b)

- Starting to use shorter runs and alternate furrows on furrow irrigation systems.
- Tailwater return systems are encouraged. Two were installed in 1989. Doesn't say how many fields use this currently or historically.

(Hoffman, G.J., D.W. and Meek, J.L. Gartung. 1988)

- See pp. 1-6 for discussion of irrigation scheduling and management, and especially on causes of deep perc.

(Westlands Water District. 1989)

- See water destinations and efficiency terms and equations.
- See notes on irrigation practices and potential improvements.

SALINITY OF DRAINAGE WATER

(Ayars, J.E. and G. Schrale. 1990)

- Figures 25 through 28 show flow along with concentrations and total loads of salts and boron, for 1986-87. Concentrations appear to fluctuate 180 degrees out of phase with the sinisoidal drainage flow curve, but loads follow drainage flow very closely. It appears that reducing flows will reduce loads.
- Table 11, "Drainage water yield for the drainage test sites from July 1988 to December 1989", p. 79. Shows the drainage depth for 4 field sites. Author's discussion shows that for A1 and B2, the amount recorded is far less than calculated based on IE, indicated deep perc is by-passing the drains, or a mistake somewhere, and that for B1, the amount recorded is far greater than estimated from IE's, indicating transfer of upslope drainwater from adjacent fields.
- Author's notes: drainage spikes follow irrigations predictably, and flow concentrations from tile drains is constant with time, tho varies widely from site to site.(Broadview Water District, 1989)
- Bar graphs of Salt load in water released through Broadview outlet (Tons), by month, 1986-89, bar graph. Also cumulative bar graph.
- Table of salt load in discharges to San Joaquin river (?) (Tons), by year 1984-89.
- Broadview WD drainage outlet, EC, Se, B, Mo, by crop year 1988-89.

(Central California Irrigation District, 1990)

- Reportedly, the area contributing the worst quality drainage water is the Camp 13 Study Area (6,000 A), which is in CCID's control. Reportedly, it is the only drainage water source within CCID that lowers downstream water quality. The outflow is 2 to 3 cfs, 5000 ppm TDS, 5 to 10 ppm Bo, and 3 to 30 ppm Se.

(Charleston Drainage District, 1990)

- Graph of Se load (lbs), by month, for years 1986-89.

(Hoffman, G.J. and G. Schrale. 1988)

- Figure 6, "Variation of the concentration of selenium in the annual subsurface drainage discharge by individual drainage systems for 1987", p. 14.

(Hoffman, G.J., D.W. Meek and J.L. Gartung, 1988)

- Table 1, "Chemical characteristics of subsurface darin waters on west side of the San Joaquin Valley, California", p. 12, adapted from Deverel, et al., 1984 (see references). Shows Ec, Boron, and Se, and min, ave, and max values for an average of 30 samples.

(J.M. Lord, Inc. 1989)

- Same as for (J.M. Lord, Inc. 1988), except for the following year, and that irrigation evaluations appeared to be of higher quality.

(J.M. Lord, Inc. 1988)

- See Chapter III, Results, for irrigation evaluations on 3 study fields. These fields were under JM Lord supervision, so irrigation practices were improved somewhat based on first irrigation or first set evaluations. Only single furrow evaluations were used to determine the DU's. Gives tile and deep drain flows and chemical analyses for season.

(J.M. Lord, Inc., 1987)

- Figures 5, "Annual Flow Histogram - % of Sumps with Flow in Given Range", p. 16. Shows variability of annual tile drain flow (AF/AC). Area of study is nearly identical to ours.
- Figure 6, "EC Histogram - % of Sumps with EC in Given Range", p. 16. Shows variability of average EC of tile drain water (DS/M). Area of study is identical to ours.
- Figure 7, "Boron Histogram... same idea
- Figure 8, "Selenium Histogram .. same idea
- Table 4, "Sample Populations for Histograms

(San Joaquin Valley Drainage Program, 1987)

- Table 4, "Drainage Water Concentrations of Trace Elements", p 14. Contains min, max, and median concentrations (ppm) of various trace elements. From data collected during the years 1984-86, from 40 sights within the west side of the San Joaquin Valley.
- Map "Areas with highest soil levels of selenium", p 15. Essentially, two areas are shown, the Panoche fan area west of Fresno, and an area south of Kettleman City.
- Map "Water-Quality Monitoring Network", p 16. Shows sub-surface and surface drainage water monitoring sights for SJVDP.

(Wichelns, 1988)

- Table 5, "Summary of Water Quality Data Collected from Subsurface Drainage Sumps in the Broadview Water District, Crop Year 1988", p. 15. Shows Ec, Boron, Se, Molybd, and arsenic min, max, and average.
- Table 6, "Summary of Delivery and Drainage Water Quality in the Broadview Water District, Crop Year 1988", p. 16. Shows Ec, Boron, Se, and Molybd. for canal deliveries, field deliveries, main district drain, and outlet.

AMOUNTS OF DRAINAGE AND RETURN FLOW

(Ayars, J.E. and G. Schrale. 1990)

- Figure 13, "Map of existing subsurface drainage systems in the Panoche Water and Drainage District", p. 46.
- Figure 14, "The 1987 tailwater groupings in relation to the subsurface drained areas", p. 47.
- Figure 15, "The 1988 tailwater groupings in relation to the subsurface drained areas", p. 48.
- Figure 16, "Distribution of 1987 combined drainage calculated from the irrigation efficiency data", p. 50.
- Figure 17, "Distribution of 1988 combined drainage calculated from the irrigation efficiency data", p. 51. Shows areas with seasonal drainage amounts of <134, 135-299, and >300 mm.
- Figure 21, "Total water delivery in the Panoche, Eagle Field, Oro Lomo, and Mercy Springs Water Districts and drain flow measured the District outlet (PE-14) for the 1987 and 1988 water years", p. 21. Author points out that the largest volumes of drainage occur in the summer months, and thus that this time period provides the greatest opportunity for reduced drainage flow; even though the greatest drainage to irrigation amount ratios occur in the fall and winter, during pre-plant irrigations.
- Figure 24, "Running total of monthly drainage flow for previous 12 months from PE-14", p. 61. Shows monthly flows (TAF) for 87 and 88 crop years.

(Broadview Water District, 1989)

- Volume of water released through Broadview outlet (AF), by month, 1986-89, bar graph.
- Drainage discharge (AF) and area drained (A), 1982-88, by year.
- Table of subsurface drainage water (AF), 1986-89.
- Total sub-surface drainage water (AF), by drainage system (sump number), 1986-89.
- Table of discharges to San Joaquin river (AF), 1984-89, by year.

(Broadview Water District, 1982)

- Estimated total subsurface drain discharge, 1981, 5750 AF.

(Broadview Water District, 1984)

- Tile, tailwater, and freshwater leaving district (AF), by month, for 1984.

(Central California Irrigation District, 1985)

- Table of annual average re-circulated surface drainage water (33,000 AF), and by month.
- Table of annual average surface drainage that enters CCID (42,678 AF), and by month.
- Table of annual average surface drainage that leaves CCID (79,156 AF), and by month.

(Charleston Drainage District, 1990)

- Average annual drainage water discharged from district is 4,000 AF per year. Most of this flow occurs between March and August.
- Table of drainage discharges from district (AF), by month, for years 1986-89. Also, a graph of same data.
- Estimated that 3,600 of the 4,275 acres have drain systems.
- In the last few year, some of the drain water was mixed with tail water and used on pasture land.

(Firebaugh Canal Water District. Mystery paper)

- Estimates of sub-surface flows from upslope regions: 1000 AF into Firebaugh Canal WD and 1500 AF into Broadview WD.

(Hoffman, G.J. and G. Schrale. 1988)

- Figure 5, "Variation of drainage discharge for individual drainage systems throughout the district during 1987", p. 13. Shows tile drain discharge areas for amounts of <60, 60-135, 135-210, 210-300, 300-600, and >600 mm/yr.

(Pacheco Water District. 1990)

- Table 1, "Monthly Drainage Discharge in Acre-Feet", p. 5. For years 1986-88. Totals were 8618, 7630, and 4790 AF. The reduction is due to re-circulation efforts.
- Figure 2, "Pacheco W.D. Discharge", p. 8. Shows monthly flows for 1986-89.

(Pacheco Water District. 1982)

- Drainage estimate for 1981 (based on 1980), 4200 AF. District area, 4460 A; area with on-farm drains, 3050 A.

(Panoche Drainage District. 1989)

- Table 1, "Monthly Drainage Discharge" (AF), p. 7. Shows drainage from district, for each month, for years 1986-88. Annual totals average 32,000 AF.

(Panoche Water District. 1982)

- Estimated 1981 subsurface drain discharge was 18,000 AF/yr.

IRRIGATION DISTRICT DRAINAGE AND CONVEYANCE MAPS

(Broadview Water District, 1984)

- Description of on-farm drainage facilities. All sections within BWD have some tile, and discharge to a sump and are then pumped. Groundwater was under control.
- Description of district collector drains and their operation. All drains serve both sub-surface and tailwater. Have the option at the Nees pump station to recirculate the drainage water, or release drain, or drain/fresh water into a drain in Firebaugh Canal Co. No sub-surface is allowed into the district as surface flow from lands outside the district.
- Of the 16,275 AF of tile/tail/fresh water released in 1984, it was estimated that 3,500 AF was tile water. 6,000 AF of tile/tail water was recirculated, of which it was estimated that 1,700 AF was tile water.
- An overview of general history concerning drain water, with maps. One page.

(Broadview Water District, 1982)

- Map of open drains (carrying surface and sub-surface water), and of tile drainage outlets (all pumps).

(Central California Irrigation District, 1990)

- There are several independent drainage districts within CCID: the Poso Canal Co (50,000 A), the Dos Palos Drainage District (4,500 A), the Charleston Drainage District (500 A), Main Drain Group (6,000 A), the Gustine Drainage District (20,000 A). For these areas, CCID has little control.
- It was believed that the area contributing the worst quality drainage water is the Camp 13 Study Area (6,000 A), which is in CCID's control. It was believed to be the only drainage water source within CCID that lowered downstream water quality. The outflow was 2 to 3 cfs, 5000 ppm TDS, 5 to 10 ppm Bo, and 3 to 30 ppm Se.
- Reportedly, the advent of high water tables resulted in deep drains and then tile drains. Initially, the recovered water was of high quality, but when upslope lands came under irrigation, the sub-surface drainage water quality deteriorated until it was unsuitable for re-circulation or discharge.

(Central California Irrigation District, 1990d)

- There is an undetermined supply of water to CCID from upslope tailwater and re-circulated drainage return flows. (Not clear from text whether drainage is from up-slope area or from within the district).
- CCID re-circulates an average of 30,000 AF tile and tail water, annually.

(Firebaugh Canal Water District, 1990b)

- Map of district, with conveyance and drainage facilities shown.

(Hoffman, G.J. and G. Schrale. 1988)

- Figure 2, "Subsurface drainage systems installed in the Panoche Water District", p. 10. Shows all tile system laterals for the whole district.

(J.M. Lord, Inc., 1987)

- Figure 1, "Drainage Study Area Map", p. 4. Shows for our area, the district boundaries, and the field area with tile drains (incomplete, since information was sketchy).

(Panoche Drainage District. 1989)

- Drainage system consists of deep open drains, which receive tile drain water from sumps, some surface drain water, and some intercepted subsurface water due to depth of the drains.

(Panoche Water District. 1982)

- Drained acreage of 18,000 A out of 39,423 total district acreage.

DISTRICT CONVEYANCE DESCRIPTION (unlined, piped)

(Broadview Water District, 1989)

- Broadview WD, with legend showing pump stations, turnouts, pipelines, canal/laterals, and drains. Not too clear, but usable.

DISTRICT DELIVERY POLICIES (flexibility)

(Broadview Water District, 1989)

EXTENT OF HIGH WATER TABLE

(Central California Irrigation District, 1984)

- Table of shallowest and deepest readings to ground water level (ft), by month, for calendar years 1981-3, for "Los Banos Study Sub-area".
- Tables of shallowest and deepest readings to ground water level (ft), by month, for 1983, average (for district?).

(Firebaugh Canal Company, 1985)

- Total acres tiled was 12,000 acres, out of a district acreage of 22,600 acres. Tile was recently added due to extensive irrigation upslope of the district.

(Panoche Water District. 1982)

- 22,000 A with <10' water table, out of 39,423 total district area.